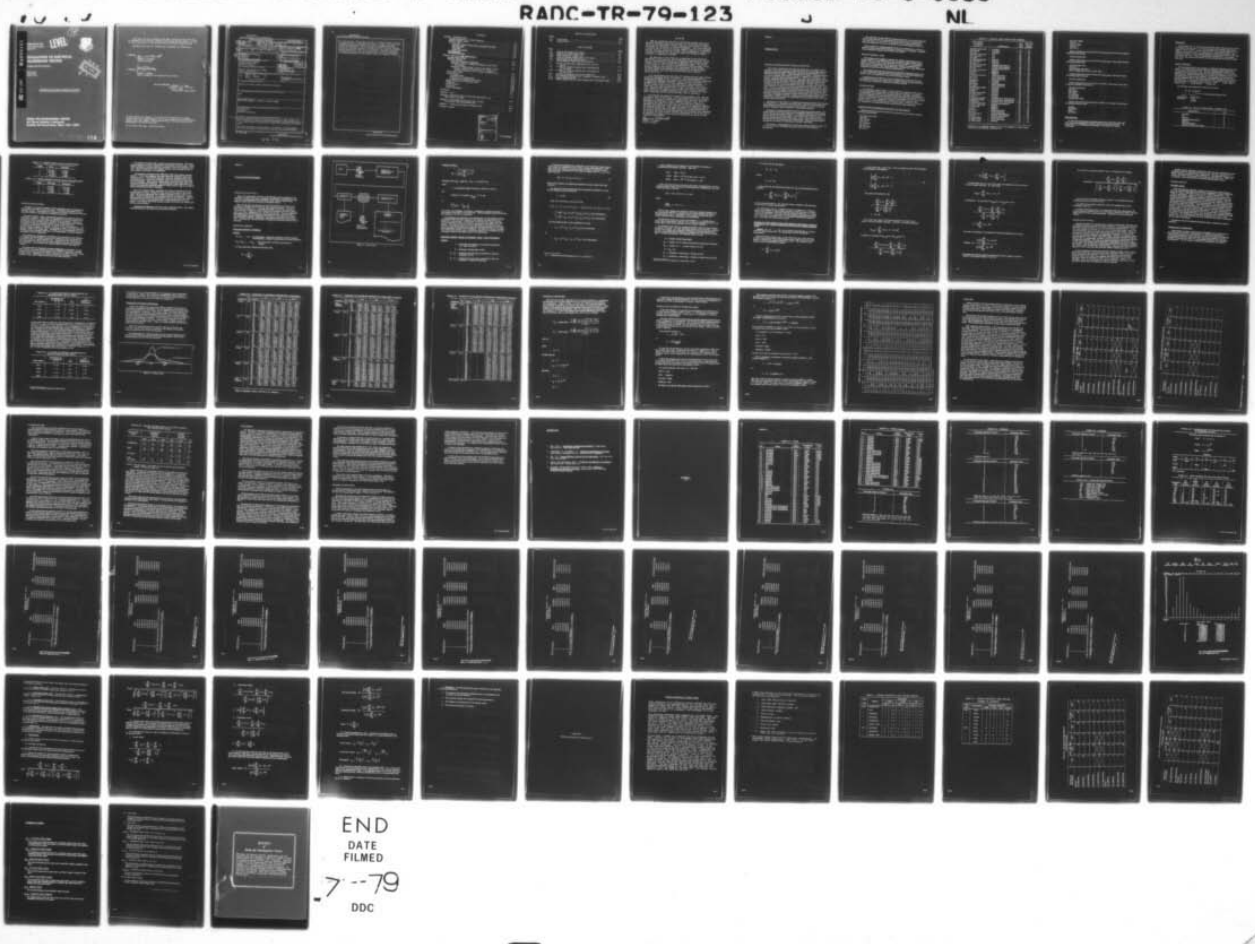
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RADC-TR-79-123
Final Technical Report
April 1979

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# EVALUATION OF ELECTRICAL GUARDBAND TESTING

Hughes Aircraft Company

Greg Allen
John Angus
Bruce Clark




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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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Electrical guardband testing of microcircuits in lieu of 100% testing at the device temperature extremes has long been championed by device manufacturers as a cost effective means of guaranteeing reliable device performance in military systems.

This report describes a detailed study of the validity of the guardbanding concept and the effects of manufacturer, datecode, and reliability grade

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upon these devices. Through the utilization of intensive testing techniques in conjunction with the development of a series of linear, log-linear, and exponential mathematical models a high degree of guardband test limit validity was established. Further analysis of the data utilizing advanced statistical techniques resulted in the development of a method for accurately setting guardband test limits on most parameters. Additional correlation analysis was performed on the test samples resulting in the establishment of the interchangeability of JAN, 883B processed, and commerical devices.

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ACCESSION for
NTIS White Section
DDC Buff Section
UNANNOUNCED
JUSTIFICATION
BY
DISTRIBUTION/AVAILABILITY CODES
Dist.
A

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## EVALUATION

RADC has recognized the need to continuously evaluate new quality assurance procedures that offer potential for simplifying solid state device testing requirements without compromising the overall reliability performance of the devices in military equipments. This study addresses a specific type of electrical testing, commonly referred to as guardband testing, that many microcircuit vendors have recommended be approved as an optional substitute for 100 percent electrical testing of static parameters at temperature extremes.

The objective of this effort was to determine if the electrical performance of microcircuits can be adequately characterized by testing only at room temperature conditions to guarantee their electrical performance across a specified operating temperature range. The results of this study will be utilized to evaluate what simplifications, if any, should be made in the electrical test requirements of MIL-STD-883, "Military Standard Test Methods and Procedures for Microelectronics" and MIL-M-38510, "Military Specification Microcircuits General Specification For."

This investigation has shown that for the microcircuit types studied, electrical guardband testing is feasible. Reliable guardband limit determination depends on such factors as device family maturity, magnitude of temperature dependent parameters, device to device variations in parameters and selection of a valid mathematical guardband model. All devices tested in this program were from mature bipolar transistor-transistor logic families consisting of small and medium scale complexities. However, there appears to be no reason why similar techniques could not be used to obtain guardband test limits on devices for other mature technology families having the same level of complexity.

The proposed test method for establishing guardband limits that was developed as part of this study, will now be made available for industry evaluation. Since most microcircuit manufacturers have been employing guardband test techniques on their commercial product lines, it is anticipated that they will cooperate in evaluating this proposed new guardband test method and be in a position to provide meaningful comments and supporting test data. RADC does not propose to recommend changes in existing MIL-STD-883 and MIL-M-38510 electrical testing procedures until microcircuit manufacturers have demonstrated that guardband test techniques are suitable for their products and that performance of the microcircuits at temperature extremes can be reliably predicted based solely on room temperature measurements.

Edward P. O'Connell

EDWARD P. O'CONNELL
Project Engineer

Section 1

# INTRODUCTION

## PROGRAM BACKGROUND AND OVERALL OBJECTIVES

Microcircuit vendors have indicated that significant cost savings could be realized, if they were permitted to substitute equivalent or guardband test procedures for the more costly temperature extreme test requirements of MIL-STD-883 and MIL-M-38510. Data submitted by one vendor, covering an evaluation that he designed and conducted, appears to support this contention. The ability to perform effective guardband tests is a function of the vendor process control, technology and device maturity. Therefore, guardband testing can only be prepared for an individual circuit by performing a detailed analysis of the test data as the device reaches a reproducible state. In many cases the test procedures that are used for guardband testing are proprietary and would not be made available for inclusion in military specifications as alternate tests. However, if it can be determined that guardband tests provide an adequate assurance of microcircuit performance over the full operational temperature range, then it may be possible to establish methods by which a vendor can qualify to use his alternate or guardband procedures without divulging the exact methods of testing. This study is intended to provide a comparison of the electrical performance capabilities of select microcircuit types that have been tested to both "JAN" and various vendor procedures.

The objective of this study is to validate the technical acceptability and assess the reliability risk, associated with using vendor equivalent of guardband electrical testing procedures for monolithic microcircuits, in lieu of 100 percent electrical testing of static parameters at temperature extremes.

This effort is designed to generate data for select microcircuit types, indicating if the electrical performance can be adequately characterized by testing only at ambient temperature conditions, to guarantee their electrical performance across the full operating range. The results of this effort are to be utilized in determining what simplifications, if any, can be made in MIL-STD-883 and MIL-M-38510 electrical test requirements, without compromising the operational and reliability performance of military equipments.

The electrical interchangeability of 883B and commercial grade devices with JAN devices shall be determined through an analysis of the parameter distributions.

The compliance of each 883B and commercial devices to its our procurement specification and to the corresponding MIL specification will be determined. This information is to be used as an indication of the overall performance of 883B and commercial devices as compared to the corresponding JAN devices.

The procedure for setting guardband limits will be determined, as well as a method of determining when guardband test techniques can be applied. Examples of the calculations required are included in the results.

## SPECIFIC PROGRAM TASKS

This program was designed to establish the validity of guardbanded device testing limits at 25°C as substitutes for the temperature extreme test requirements (-55°C and +125°C) of MIL-STD-883 and MIL-M-38510. The guardband test limit characterizations were developed to a number of different digital device types including 2 and 3 input Nand gates, flip-flops and 8 input multiplexer integrated circuits from seven different manufacturers.

The resultant data base was analyzed for compliance to guardband test limits as well as parameter distributions and compliance to JAN Mil Slash Sheets Spec limits as well as manufacturers data sheet performance limits.

Applications of this effort can result in simplification of MIL-STD-883 and MIL-M-38510 electrical test requirements without compromising the operational and reliability performance capabilities of military systems.

## PARTS FOR TEST

All components listed in Table 1-I were tested for compliance with the electrical performance characteristics to which they were procured. In addition, all components were tested to the applicable military JAN slash sheet specifications for compliance with electrical performance characteristics of MIL-M-38510 Table I in accordance with the electrical test requirements of Table II for Class B devices and the Group A inspection conditions of Table III except that Subgroups 10 and 11 were performed on a 100 percent basis. Tables I, II, and III are contained in the applicable military specifications referenced below.

### Applicable Military Specifications Electrical Test Plan (Typical)

Military Specification MIL-M-38510/1B, device type 03 was used to test the following microcircuits:

JM 38510/00103 BCX
9N10 DM
9N10 DM QB
ITT 5410J
ITT 5410J/B2
MC 5410 L
MC 5410 BEX
DM 5410 J

TABLE 1-I. TABLE OF TEST SAMPLE PART NUMBERS

| Part Number – As Required by S.O.W. | Manufacturer | Part Ident Code | Minimum Samples Tested* |
|---|---|---|---|
| JM 38510/00103 BCX | Fairchild | AJ | 50 |
| 9N10 DM QB | Fairchild | AE | 100 |
| 9N10 DM | Fairchild | AA | 100 |
| JM 38510/00103 BCX | ITT | BJ | 50 |
| ITT 5410J (B2) | ITT | BE | 100 |
| ITT 5410J | ITT | BA | 100 |
| JM 38510/00103 BCX | Motorola | CJ | 50 |
| MC 5410 BEX S | Motorola | CE | 100 |
| MC 5410 L | Motorola | CA | 100 |
| JM 38510/00103 BCX | National Semiconductor | DJ | 50 |
| DM 5410/883 B | National Semiconductor | DE | 100 |
| DM 5410 | National Semiconductor | DA | 100 |
| JM 38510/00103 BCX | Signetics | EJ | 50 |
| RB 5410 F | Signetics | EE | 100 |
| S 5410 F | Signetics | EA | 100 |
| JM 38510/00103 BCX | Texas Instrument | FJ | 50 |
| SNC 5410J | Texas Instrument | FE | 100 |
| SN 5410J | Texas Instrument | FA | 100 |
| 9S10DM QB | Fairchild | AH | 100 |
| 9S100DM | Fairchild | AD | 100 |
| SNC 54S10J | Texas Instrument | FH | 100 |
| SN 54S10J | Texas Instrument | FD | 100 |
| JM 38510/00104 BEX | Fairchild | AN | 50 |
| 9312DM QB | Fairchild | AF | 100 |
| 9312DM | Fairchild | AB | 100 |
| JM 38510/01402 BEX | Motorola | CK | 50 |
| MC 9312 BLX S | Motorola | CF | 100 |
| MC 9312 L | Motorola | CB | 100 |
| JM 38510/01402 BEX | Advanced Micro Development | GK | 50 |
| 0713931251X (883B) | Advanced Micro Development | GF | 100 |
| 0713931251X | Advanced Micro Development | GB | 100 |
| JM 38510/00201 BCC | National Semiconductor | DL | 50 |
| JM 38510/00201 BCX | Signetics | EL | 50 |
| S 5472F/883B | Signetics | EG | 100 |
| S 5472 F | Signetics | EC | 50 |
| SNC 5472 J | Texas Instrument | FG | 100 |
| SN 5472 J | Texas Instrument | FC | 100 |
| DM 5472J/883 B | National Semiconductor | DG | 100 |
| DM 5472 J | National Semiconductor | DC | 100 |
| JM 38510/00201 | Texas Instrument | FL | 50 |
| JM 38510/00602 | Texas Instrument | FP | 50 |
| JM 38510/00104 | Signetics | EN | 50 |

*Includes 5 or 10 additional samples per part type depending on initial sample size used as test program verification etc.

DM 5410 J/883B
S 5410 F
S 5410 F/883B
SN 5410 J
SNC 5410 J

Military Specification MIL-M-38510/1B, device type 04 was used to test the following microcircuits:

JM 38510/00104 BCX

Military Specification MIL-M-38510/2E, device type 01 was used to test the following microcircuits:

JM 38510/00201 BCX
DM 5472 J
DM 5472/883B and 5472 F
S 5472 F/883B and N 5472 J and NC 5472 J

Military Specification MIL-M-38510/6B, device type 02 was used to test the following microcircuits:

JM 38510/00602 BCX

Military Specification MIL-M-38510/14A (USAF), device type 02 was used to test the following microcircuits:

JM 38510/01402 BCX
9312 DM
9312 DMQB
MC 9312L
MC 9312BLX
0713931251X
0713931251X (883B)

Military Specification MIL-M-38510/70 (USAF), device type 05 used to test the following microcircuits:

9S10DM
9S10DMQB
54S10J
SNC54S10J

## Data Recording

All tests and measurements performed above were recorded in hard copy form along with datalogging to magnetic tape for further data analysis. All devices with out-of-specification parameters were retested for failure verification.

## Description

Device Selection: All microcircuits that were used in this study were sealed in hermetic, dual-in-line, 14 or 16 pin packages with operating temperature range of -55°C to 125°C. These microcircuits were procured either from the contractor's in-house store or a manufacturer's authorized distributor and, whenever possible, the test samples consisted of devices from two or more different data code lots. Table 1-I identifies the manufacturer, part number, part serial code number and quantity of microcircuits that were tested during this study.

## Device Traceability

All test sample devices were marked according to the following master code system. For traceability during the test and evaluation program each device was assigned a five character code. The first character was a letter corresponding to the manufacturer of the device as shown in Table 1-II. The second character was a letter corresponding to the device type as shown in Table 1-III The last three characters were numbers corresponding to the device serial number beginning with 001 and continuing in sequence through the last device in the test series. A new serial number sequence was started for each combination of the first two characters of the code: i.e. AA001 . . . AA050, AB001 . . . AB050, BA001 . . . BA050, BB001 . . . BB050, etc.

The following is an example of a typical device code:

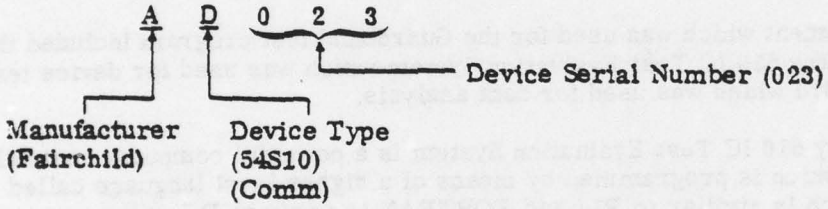



TABLE 1-II. MANUFACTURER SERIAL NUMBER CODE

| Manufacturer | Code |
|---|---|
| Fairchild | A |
| ITT | B |
| Motorola | C |
| National Semiconductor | D |
| Signetics | E |
| Texas Instrument | F |
| Advanced Micro Development | G |

TABLE 1-III. DEVICE TYPE SERIAL NUMBER CODE

| Device Type | | Code |
|---|---|---|
| 5410 | Commercial Parts | A |
| 9312 | | B |
| 5472 | | C |
| 54S10 | | D |
| 5410 | MIL-STD-883 Class B Parts | E |
| 9312 | | F |
| 5472 | | G |
| 54S10 | | H |
| JM 38510/00103 BCX | JAN Parts | J |
| JM 38510/01402 BEX | | K |
| JM 38510/00201 BCX | | L |
| JM 38510/00205 BCX | | M |
| JM 38510/00104 BCX | | N |
| JM 38510/00602 BEX | | P |

INSTRUMENTATION

The equipment which was used for the Guardband test program included the Fairchild Sentry 610 IC Test Evaluation System which was used for device testing and the IBM 370 which was used for data analysis.

The Sentry 610 IC Test Evaluation System is a powerful computer controlled test system which is programmed by means of a higher level language called FACTOR which is similar to PLI and FORTRAN to perform DC parametric, AC parametric and functional tests. It can also be programmed to do data analysis. The Sentry 610 specifications are given in Tables 1-IV, 1-V, and 1-VI.

An important part of the Sentry 610 IC Test Evaluation System is the automatic handler and environmental chamber. The automatic handler inserts the device under test into the contactor inside the environmental chamber. This chamber provides a temperature stability of $\pm$ 1%C from -73°C to +150°C.

Although the Sentry is capable of performing analysis, to increase efficiency, the IBM 370 was used to perform off-line data analysis. To facilitate this processing, data was recorded by the Sentry on magnetic tape on 9 tracks at 800 bpi which is an IBM compatible format. Hard copy data was also recorded by the Sentry using the Data Products Model 8428 high speed line printer.

## TABLE 1-IV. FORCE AND MEASURE RANGES WITH 2V/2mV OPTION

| Module | Statement | PROGRAMMABLE VALUE/RESOLUTION | | | | |
|---|---|---|---|---|---|---|
| | | Range 0 | Range 1 | Range 2[2] | Range 3[2] | Range 4 |
| PMU | Force Voltage | | 0 to 2.046V/2 mV | 0 to ±10.23V/10mV | 0 to ±40.92V/40mV | 0 to ±102.3V/100mV |
| PMU | Set PMU ForceV | | 10 to 2.046V/2 mV | 0 to ±10.23V/10mV | 0 to ±40.92V/40mV | 0 to ±102.3V/100mV |
| PMU | Force Current | 0 to ±1.023uA/1nA | 0 to ±102.3uA/.1uA | 0 to ±10.23mA/10uA | 0 to ±102.3mA/.1mA | |
| PMU | Set PMU ForceI | 0 to ±1.023uA/1nA | 0 to ±102.3uA/.1uA | 0 to ±10.23mA/10uA | 0 to ±102.3mA/.1mA | |
| PMU | Set PMU Sense Voltage | | 0 to ±2.046V/2mV | 0 to ±10.23V/10mV | 0 to ±40.92V/40mV | 0 to ±102.3V/100mV |
| PMU | Set PMU Sense Current | 0 to ±1.023uA/1nA | 0 to ±102.3uA/.1uA | 0 to ±10.23mA/10uA | 0 to ±102.3mA/.1mA | |
| DPS | Force VF | | 0 to ±2.046V/2mV | 0 to ±10.23V/10mV | 0 to ±40.92V/40mV | |
| DPS | Force IF | | | 0 to ±102.3mA/.1mA | 0 to ±1.023A/1mA | |
| DPS | Enable Trip | | | 0 to ±102.3mA/.1mA | 0 to ±1.023A/1mA | |
| DPS | Enable TripV | | | 0 to ±10.23V/10mV | 0 to ±40.92V/40mV | |
| RVS | Set (S0/S1) | | 0 to 2.046V/2mV | +6.0V to -10.23V/10mV | +6.0V to -30.72V/40mV[1] | |
| RVS | Force E | | | +6.0V to -10.23V/10mV | +6.0V to 30.72V/40mV[1] | |

NOTES

[1] Max limit is -30.72V for a 5 Mhz Pin Electronics Board, -16.00V for a 10 Mhz Pin Electronics Board.
[2] Current ranges depend on the hardware module; 102.3 milliamps is full scale in range 2 for power supplies, but is full scale in range 3 for the PMU.

TABLE 1-V. PERIOD RANGE, SCALE AND RESOLUTION

| Range | Scale | Resolution |
|---|---|---|
| 0 | 40 μsec | 10 nsec |
| 1 | 400 μsec | 100 nsec |
| 2 | 4 msec | 1 μsec |
| 3 | 40 msec | 10 μsec |

TABLE 1-VI. TIMING GENERATOR RANGE SCALE AND RESOLUTION

| Range | Full-Scale | Resolution |
|---|---|---|
| 0 | 10 μsec | 0.16 nsec |
| 1 | 100 μsec | 100 nsec |
| 2 | 1 msec | 1 μsec |
| 3 | 10 msec | 10 μsec |

DIFFICULTIES/SOLUTIONS

Problems in a study as complex as RADC guardband are to be expected and the problems encountered were not unusual. Mechanical difficulties with the automatic handler, room temperature fluxuations, and test equipment deficiencies were all corrected to facilitate the completion of the study.

The device handler, being a complicated mechanism is subject to failure at temperature extremes. Heat causes the expansion of metal which induces friction and the eventual jamming of the moving parts in the handler. Even more troublesome is the low temperature extreme. At temperatures below freezing, the moist environment of the test chamber causes a layer of frost to accumulate on the handler mechanism, as well as on the parts themselves. This not only causes jamming, but continuity problems as well, as the frost prevents effective contact to the device pins. Jamming due to metal expansion can be prevented by precise clearance adjustment of the mechanism, but the low temperature failure is more complicated.

The problem was eliminated by producing a dry environment in the chamber. The chamber was first purged of moist air by opening the door and forcing dry $N_2$ into the cavity at a fairly high flow rate. Then the door was closed and the flow rate reduced so that only a few pounds of positive pressure was maintained in the chamber. This prevented any moisture laden air from reentering the chamber.

The sample devices themselves presented difficulties to the handler, in that many devices of the same sample group were of different dimensions. Package thickness and package end-to-pin spacing, both critical to proper handling, varied in many groups. Realignment for these variations was necessary in some instances, while others required odd parts to be tested separately.

The Sentry 610 tester itself, caused an occasional problem. The tester would sometimes fail due to temperature fluctuations in the test area. It was finally necessary to enclose this area, isolating it from the remainder of the Lab. Separate temperature and humidity controls were installed to allow a more stable environment to be maintained.

Documentation presented some difficulties which were mainly operator induced. A few of the magnetic data tapes generated during the study were written in error. These errors included: improper computer control and termination marks, incorrect parametric limits and data format and wrong device numbering. These errors delayed some tapes from being used in the computer assisted data reduction. The improperly written tapes were corrected with separately generated software, which allowed a tape to be altered without destroying the data it contained.

Due to its complex nature, the Sentry 610 Tester is limited in its time measurement accuracy. Delays from the system electronics to the device under test become significant when testing propagation times in the 5-10 ns range. However these delays are consistent and can be measured. Software which measure and stores the delay between each pin the tester was used in a "de-skew" routine in each program where a high speed device was to be tested. This routine allowed the system accuracy of 160 ps to be achieved for all time measurements.

Although these difficulties did cause some unexpected delays, the validity of the end results of the study was not adversely affected.

Section 2

# DATA ANALYSIS DESCRIPTION

## PROCESS (FLOW OF DATA)

Before the mathematical analysis of the test data could be conducted it was necessary to create a data base, containing all parametric measurements along with their corresponding test specifications, which could be utilized by the Hughes-Fullerton IBM 370/AMDAHL 470 computer system.

Since all test data was generated by the Fairchild Sentry 610 tester it was necessary to translate the raw data into IBM compatible format. The flow of data is shown in Figure 2-1. Following translation, the data was sorted and "preprocessed" to obtain the fraction defective (according to the given specification, e.g., JAN, Commerical, etc.) for each lot of parts. Next, the parameter measurements are stored (along with their specified upper and lower limits, test temperature, and test description) temporarily on disk where they remain until descriptive statistics, histograms, and regression analyses can be generated. Following this, the data on disk is stored on an IBM library tape for future reference.

## REDUCTION METHODS

### Descriptive Statistics, Histograms

Notation:

$X_1, X_2, \ldots, X_n$ - are independent, identically distributed random variables corresponding to repeated measurement of a given parameter.

$X_{(1)} \leq X_{(2)} \leq \ldots \leq X_{(n)}$ - the sample above ordered from smallest to largest.

For each parameter measured the sample mean

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \quad ,$$

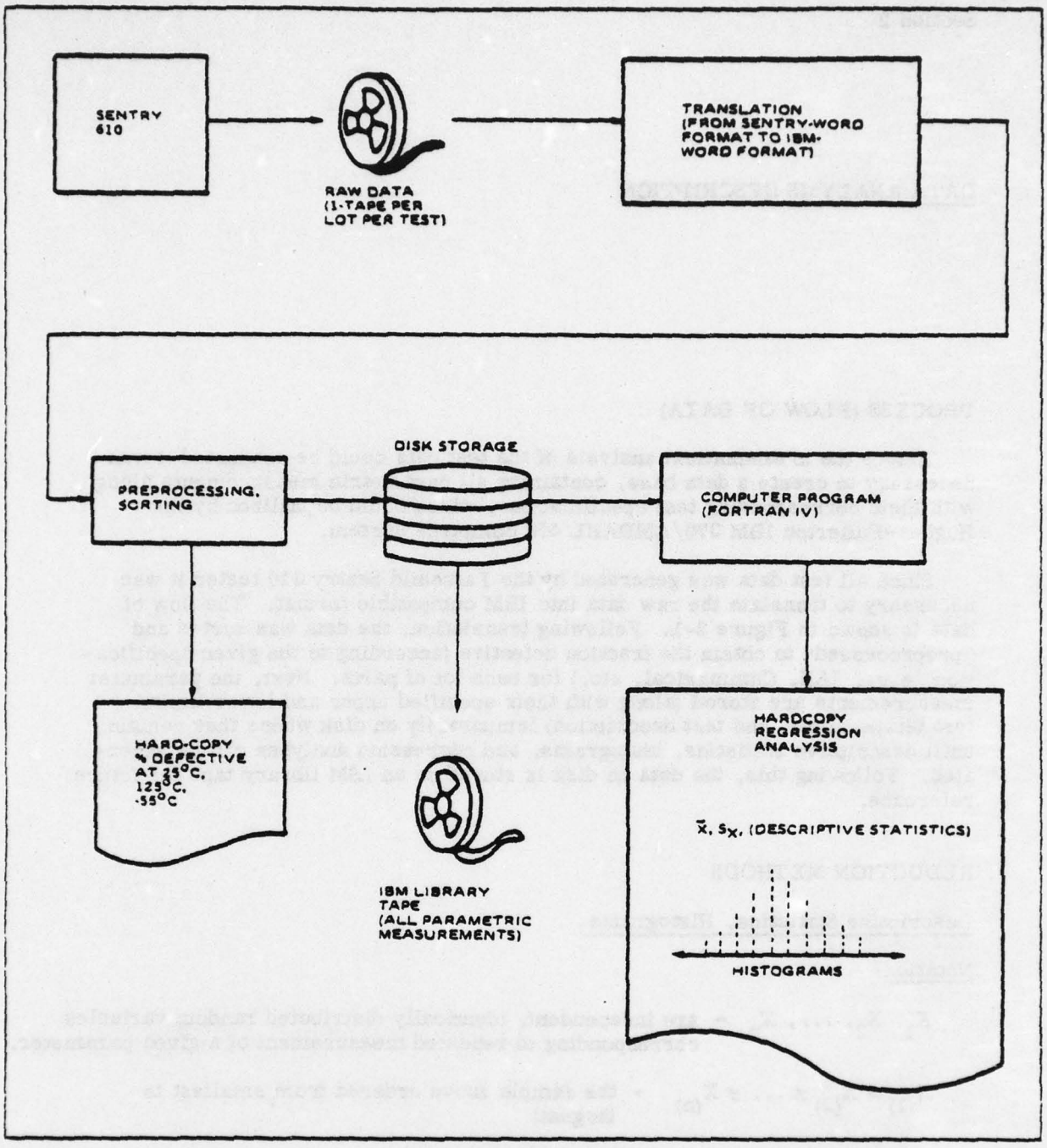



Figure 2-1. Flow of Data

Standard Deviation

$$S_X = \sqrt{\frac{1}{(n-1)} \sum_{i=1}^{n} (X_i - \bar{X})^2} \quad ,$$

maximum value $X_{(n)}$, range $X_{(n)} - X_{(1)}$, 0.10 quantile $X_{(r)}$

where

r = the greatest integer less than or equal to (0.10) x n,

and

median or 0.50 quantile $X_{\left(\frac{n+1}{2}\right)}$ if n is odd

or

$$\frac{1}{2}\left(X_{(n/2)} + X_{\left(\frac{n}{2}+1\right)}\right)$$

if n is even, are computed. In addition, a histogram is printed to show the approximate distribution of the parameter. Some histograms along with descriptive statistics are shown in Appendix 2.

The histograms are generated by partitioning the real line segment between preselected limits into equal segments, and counting the number of the $X_j$'s which fall in each interval. In each case, we used 20 equal "class" intervals, and our preselected limits were chosen as the sample 0.95 quantile and 0.05 quantile. $X_{(1)}$ and $X_{(n)}$ were not used as preselected limits since for large n, $X_{(n)} - X_{(1)}$ was often so large as to cause the individual intervals to be to large to obtain adequate "spread" in the histogram. By using the 0.05 and 0.95 quantiles, 90% of the observed mass is effectively utilized in the histogram and this is enough to obtain a fairly good picture of the distribution.

Regression Analysis, Setting of Guardbands, Fisher - Irwin Test Statistic

Notation:

Y = parameter measurement at an extreme temperature (i.e. -55°C or 125°C)

X = parameter measurement at 25°C

$X_L$, $X_u$ = specified lower and upper (respectively) limits for parameter at 25°C

$Y_L$, $Y_u$ = specified lower and upper (respectively) limits for parameter at extreme temperature

An electrical guardband test is described as the imposition of upper and/or lower limits on a parameter at 25°C which if passed would guarantee a measured value at the extreme temperature which is within its specified limits. Stated precisely, guardbands are determined by finding values $G_L$, $G_u$ (if they exist) such that

$$P\left\{Y_L \le Y \le Y_u \,\middle|\, G_L \le X \le G_u\right\} = 1 \tag{1}$$

where $P\{A|B\}$ denotes the conditional probability of event A given that B has occurred.

Our approach to this problem has been to postulate the existence of a continuous monotone function g such that

$$Y = g(X) . \tag{2}$$

Under this assumption, from (2) we have

$$P\left\{Y_L \le Y \le Y_u \,\middle|\, G_L \le X \le G_u\right\} = P\left\{Y_L \le g(X) \le Y_u \,\middle|\, G_L \le X \le G_u\right\}$$

$$= \begin{cases} P\left\{g^{-1}(Y_L) \le X \le g^{-1}(Y_u) \,\middle|\, G_L \le X \le G_u\right\} \text{ if g is increasing} \\ P\left\{g^{-1}(Y_u) \le X \le g^{-1}(Y_L) \,\middle|\, G_L \le X \le G_u\right\} \text{ if g is decreasing.} \end{cases} *$$

It is now apparent that (1) will be satisfied if we take

$$G_L = g^{-1}(Y_L),\ G_u = g^{-1}(Y_u) \text{ if g is increasing.}$$

or

$$G_L = g^{-1}(Y_u),\ G_u = g^{-1}(Y_L) \text{ if g is decreasing.}$$

---

* $g^{-1}(\cdot)$ denotes the inverse function of g, i.e., $g(g^{-1}(x)) = x$

Three candidates for the function g were selected on the basis of tractability and preliminary analysis. They were

$$\text{(LIN)} \quad g(X) = aX + b$$

$$\text{(LLIN)} \quad g(X) = b X^{a} \text{ (or } \ln g(X) = \ln b + a \ln X)$$

$$\text{(EXP)} \quad g(X) = e^{aX + b} \text{ (or } \ln g(X) = b - aX)$$

(LIN) was selected since it provides a first order approximation to any true function g which is twice continuously differentiable in a neighborhood of a value c since by Taylor's theorem,

$$g(X) = g(c) + g'(c)(X - c) + \phi(X)$$

where

$$\frac{\phi(X)}{(X - c)} \to 0 \text{ as } X \to c.$$

The two other models were selected to account for possible curvature in g and were chosen specially to facilitate the use of least-squares estimates of the parameters a and b. The method of least squares as applied to (LIN), (LLIN), and (EXP) will be discussed in the next section.

Non-monotonic models for g were not considered, i.e., models such as higher degree polynominals, because many of these are difficult and costly to fit to data and/or their inverse functions are not available explicitly.

For functional tests where the measured parameter takes on only two possible values (0 for pass, 1 for fail), guardband analysis is not applicable. Instead, we test to see whether the probability of passing the functional test at 25°C is the same as the probability of passing the functional test at the extreme temperature. To state this precisely, the following notation is used:

$n$ = number of parts being tested

$X_E$ = number of 1's* (failures) observed at temperature extremes

$X_N$ = number of 1's* (failures) observed at 25°C

$m = X_E + X_N$

$P_N$ = probability of observing a 1 (failure) at 25°C

$P_E$ = probability of observing a 1 (failure) at temperature extreme

*These are not to be confused as Logic State 1 and 0.

We wish to test the hypothesis

$$H_0: P_N = P_E$$

versus

$$H_1: P_N < P_E$$

When $X_E$ and $X_N$ are observed such that $X_E \geq X_N$, the following statistic is computed:

$$Q = \sum_{i=X_E}^{m} \binom{n}{i}\binom{n}{m-i} \cdot \left[\sum_{i=0}^{m}\binom{n}{i}\binom{n}{m-i}\right]^{-1}$$

Q is not computed when $X_E < X_N$ since this shows a tendency of the parameter to test better at extreme temperatures.

It is clear that $0 \leq Q \leq 1$. Values of Q close to 0 support $H_1$. It was not found to be necessary to obtain critical values for Q since in nearly all cases where Q was computed, it was quite obvious whether to reject $H_0$, i.e. values of Q on the order of $10^{-5}$ and lower were quite common (indicating acceptance of $H_1$) while most other values were 0.5 and higher (indicating acceptance of $(H_0)$. Q is called the Fisher-Irwin statistic.

Equations for Fitting Models to Data by the Method of Least Squares, Measures of Goodness-of-Fit, Using the Empirically Derived Fits for Finding Guardband Limits.

Notation: $(X_1, Y_1), \ldots, (X_n, Y_n)$ are paired measurements of a parameter; $X_i$'s being taken at 25°C, $Y_i$'s being taken at one of the extreme temperatures.

Each of the three models (LIN), (LLIN), EXP) were fit to every sequence of paired observations at each extreme temperature using the method of least squares to estimate the unknown quantities a, and b. The method of least squares involves minimizing the quantity

$$E = \sum_{i=1}^{n} (Y_i - g(X_i))^2 \quad .$$

For the (LIN) case, $g(X_i) = aX_i - b$ and the values of a and b which minimize E are solutions to the equations

$$\begin{cases} \frac{\partial}{\partial a} \sum_{i=1}^{n} (Y_i - aX_i - b)^2 = 0 \\ \frac{\partial}{\partial b} \sum_{i=1}^{n} (Y_i - aX_i - b)^2 = 0 \end{cases} \tag{3}$$

The values which satisfy (3) are

$$a = \frac{n \sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{n \sum_{i=1}^{n} X_i^2 - \left( \sum_{i=1}^{n} X_i \right)^2}$$

$$b = \bar{Y} - a\bar{X}$$

For (LLIN) case, $g(X) = b X^a$ and the solutions to $\partial E/\partial a = 0$ and $\partial E/\partial b = 0$ are not available explicitly. However, if we seek to minimize

$$E_{LLIN} = \sum_{i=1}^{n} (\ln Y_i - b' - a \ln X_i)^2$$

we obtain, as solutions to $\partial E_{LLIN}/\partial a = \partial E_{LLIN}/\partial b' = 0$,

$$a = \frac{n \sum_{i=1}^{n} (\ln Y_i \ln X_i) - \sum_{i=1}^{n} \ln Y_i \sum_{i=1}^{n} \ln X_i}{n \sum_{i=1}^{n} (\ln X_i)^2 - \left( \sum_{i=1}^{n} \ln X_i \right)^2}$$

$$b = \exp\left\{\frac{1}{n}\sum_{i=1}^{n} \ln Y_i - \frac{a}{n}\sum_{i=1}^{n} \ln X_i\right\}$$

For the (EXP) case as in the (LLIN) case, the solutions to $\partial E/\partial a = \partial E/\partial b = 0$ are not available explicitly. So, the quantity

$$E_{EXP} = \sum_{i=1}^{n} (\ln Y_i - a X_i - b)^2$$

is minimized. The solutions to $\partial E_{EXP}/\partial a = \partial E_{EXP}/\partial b = 0$ are

$$a = \frac{n\sum_{i=1}^{n} X_i \ln Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} \ln Y_i}{n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2}$$

$$b = \frac{1}{n}\sum_{i=1}^{n} \ln Y_i - a\bar{X}$$

For each fit a goodness of fit measure $\bar{R}$ calculated according to the formula

$$\text{RBAR} \equiv \bar{R} = \frac{\left(\frac{1}{n-2}\right)\sum_{i=1}^{n} (Y_i - g(X_i))^2}{\left(\frac{1}{n-1}\right)\sum_{i=1}^{n} (Y_i - \bar{Y})^2} .$$

$\bar{R}$ measures the average observed mean-square error in using g to predict Y relative to the sample variance of the $Y_i$'s.

For (LIN) the correlation between X and Y is computed by the formula

$$\text{Correlation} = \frac{n\sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{\sqrt{\left[n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2\right]\left[n\sum_{i=1}^{n} Y_i^2 - \left(\sum_{i=1}^{n} Y_i\right)^2\right]}} \quad (4)$$

For (LLIN) the correlation between ln X and ln Y is computed from (4) by replacing $X_i$ with ln $X_i$, and $Y_i$ by ln $Y_i$.

For (EXP) the correlation between ln Y and X is computed from (4) by replacing $Y_i$ with ln $Y_i$.

A value of correlation close to 1 in magnitude along with a small value of $\bar{R}$ (RBAR) indicates extremely good fit by the model in question and hence, that that model should be used to select guardbands. Examples are shown in the next section.

## PRESENTATION FORMAT

Appendix 2 contains an example of the computer printouts that were generated containing regression analyses, descriptive statistics, and histograms for every parameter at each temperature for all device types and manufacturers. Printouts were indexed by a code (e.g., 4-6, or 4-14) from which vendor, type of device, procurement grade, and test spec utilized may be ascertained. Table A-1 in Appendix 1 lists all codes with corresponding information. For each code, two sets of regression analyses were performed. The first set contained regression analysis for (LIN), (LLIN), and (EXP) models with the parameter measurements at 25°C as independent variables, and the parameter measurement at 125°C as dependent variables. The next set contained regression analyses for (LIN), (LLIN), and (EXP) models with the parameter measurements at -55°C as dependent variables, and the parameter measurements at 25°C as independent variables. The Fisher – Irwin Statistic was computed twice – once with $X_E$ as the number of failures at 125°C, and once with $X_E$ as the number of failures at -55°C.

On each regression printout the parameter sequence number could be used to determine for what type of parameter the slope, intercept, RBAR, and correlation coefficient were computed. Table A-2 in Appendix 1 lists parameter sequence numbers with their corresponding parameter types for each code. Parameter types are described in Table A-3 of Appendix 1. Table A-4 in Appendix 1 shows how to determine the unknown quantities in the (LIN), (LLIN), and (EXP) models from the regression analysis printouts.

Included with the regression printouts for each code was a histogram for each parameter measured (excluding the functional tests and cases where only one distinct value was recorded) at each temperature. Each heading contained a test number (TN) which could be used to determine the parameter type. Table A-V in Appendix 1 lists test numbers with corresponding parameter types.

## SPECIFIC RESULTS

### Guardband Limits

After examining the regression results it was seen that a large number of curve-fits were accomplished with correlation coefficients in excess of 90% indicating the validity of the models ((LIN), (LLIN), (EXP)) selected over a wide variety of parameters. Ideally, of course, to discover the exact nature of the functional relationship between the parameter measurements at 25°C and some extreme temperature is desirable and would require more research. This research would involve a detailed analysis of device physics to determine the exact relationship between each parameter and temperature. For very simple devices, this approach might be possible. For more complex devices this approach would become an almost insurmountable task. What we have found in fitting our three models is that in many cases, these simple, easy to fit models provide accurate approximations to the exact functional relationships. The only disadvantage to this approach has been the fact that good fits are rarely found on every parameter for a given device (though often half or more parameters are predictable with high correlation). The advantages are that these models are easy to fit by least squares, they are easily invertable and in all probability are easier to implement than the exact relationships.

The general method of determing guardband limits is explained in detail in Appendix 3.

### Variations due to Manufacturer

Much thought was given to discovering a meaningful way in which to quantify variations in parameter distributions due to different manufacturers. Comparing histograms was one possibility, but after examining the histograms and descriptive statistics many cases were found where sample means and standard deviations were close but corresponding histograms were extremely heterogeneous. For this reason, comparison of histograms was rejected.

Instead, the following method was used based on the ratios of sample means to standard deviations. Visual comparisons of parameter distributions based on histograms can be easily carried out by utilizing the results in Appendix 2. The advantage to the approach we used is that the test statistic has a known distribution which is extensively tabled.

If $X_1, X_2, \ldots, X_n$ are independent, identically distributed measurements of a particular parameter on a particular device from a given manufacturer, then by the central limit theorem (see [3]),

$$\frac{\sqrt{n}\,(\overline{X} - \mu)}{\sigma}$$

is approximately normally distributed with mean 0 and variance 1 for sufficiently large n (Here we've assumed that $E(X_1 - EX_1)^2 = \sigma^2 < \infty$ and $E\,|X_1| < \infty$. We've taken $EX_1 = \mu$, $\overline{X}$ as the sample mean). It follows that for large n, $Z = \sqrt{n}\,\overline{X}/\sigma$ is approximately normally distributed with mean $\sqrt{n}\,\mu/\sigma$ and variance 1. Given that n is large enough to justify the accuracy of the limiting distributions, we may form the following matrix of observations:

$$\begin{array}{cccc} Z_{11} & Z_{12} & Z_{13} & Z_{1c} \\ Z_{21} & Z_{22} & Z_{23} & Z_{2c} \\ \vdots & \vdots & \vdots & \vdots \\ Z_{r1} & Z_{r2} & Z_{r3} & Z_{rc} \end{array}$$

where $Z_{ij}$ = the Z statistic defined above computed for the ith parameter for the jth manufacturer. We assume that $EZ_{ij} = c + a_i + b_j$, i.e. that the mean of $Z_{ij}$ is a constant plus an effect due to the nature of the parameter and an effect due to the manufacturer. (All $Z_{ij}$ have variance $\approx 1$.) A test for variations due to manufacturers is now reduced to testing the hypothesis that $b_1 = b_2 = \ldots = b_c = 0$. (It is also assumed in this hypothesis that the variance of a given parameter measurement does not change with respect to manufacturer.)

Let

$$\overline{Z}_{i.} = \frac{1}{c} \sum_{i=1}^{c} Z_{ij}$$

$$\overline{Z}_{.j} = \frac{1}{r} \sum_{i=1}^{r} Z_{ij}$$

$$\bar{Z} = \frac{1}{rc}\sum_{i=1}^{r}\sum_{j=1}^{c} Z_{ij}$$

$$F = \frac{(r-1)\sum_{i=1}^{r}\sum_{j=1}^{c}(\bar{Z}_{.j} - \bar{Z})^2}{\sum_{i=1}^{r}\sum_{j=1}^{c}(Z_{ij} - \bar{Z}_{.j} - \bar{Z}_{i.} + \bar{Z})^2}$$

has the F- distribution with parameters $V_1 = (c-1)$, $V_2 = (c-1)(r-1)$ (see ref. [1], [2]). The test is then to reject the hypothesis that $b_1 = b_2 = \ldots = b_c = 0$ if the computed value of F is larger than K, where K is selected to achieve the desired size of the test.

Table 2-I gives the matrix of values used to compare manufacturers of the 5410 JAN device along with the corresponding F- statistic indicating no significant variation due to manufacturer in that case. Tables 2-II and 2-III contain F values for the JAN and 883B parts, respectively, along with accept/reject criteria.

TABLE 2-I. TEST FOR VARIATION DUE TO MANUFACTURER FOR JAN 5410 DEVICES

| | Manufacturer | | | | | |
|---|---|---|---|---|---|---|
| Parameter | Fairchild | ITT | Motorola | National | Signetics | Texas Instruments |
| VOH | 2672.34 | 2131.63 | 2664.39 | 2611.81 | 3298.48 | 2642.01 |
| VOL | 159.40 | 147.22 | 170.21 | 138.05 | 148.89 | 184.56 |
| VIC | -668.46 | -735.55 | -822.16 | -674.38 | -595.02 | -630.72 |
| IIL | -354.54 | -348.07 | -390.42 | -353.12 | -363.87 | -388.04 |
| IIH | 83.40 | 59.79 | 55.36 | 39.08 | 37.62 | 37.11 |
| II | 60.74 | 22.77 | 8.53 | 8.13 | 6.87 | 2.35 |
| IOS | -208.28 | -202.90 | -236.78 | -215.48 | -209.61 | -222.82 |
| ICC | 166.76 | 166.01 | 186.34 | 109.12 | 170.45 | 186.02 |
| TPD | 432.93 | 512.42 | 453.42 | 449.73 | 472.45 | 429.16 |

Value of F statistic is 1.12 which is insignificant so that no significant variation with respect to manufacturers is observed here. Critical values K corresponding to sizes 0.95 and 0.99 are 2.45 and 3.51, respectively, for $V_1 = 5$, $V_2 = 40$ as parameters for the F - distribution.

TABLE 2-II. F-VALUES FOR TESTING VARIATIONS DUE TO MANUFACTURER FOR JAN PARTS

| Part Number | Parameters for F - Distribution $V_1$, $V_2$ | F Value | 0.90 Quantile of F Distribution |
|---|---|---|---|
| 5410 | 5, 40 | 1.12 | 2.00 |
| 9312 | 1, 19 | 18.63 | 2.99 |
| 5400 | 1, 10 | 1.22 | 3.29 |
| 5472 | 2, 30 | 1.38 | 2.49 |

In each case if there is indeed no real variation due to manufacturer an observed value of F in excess of the 0.90 quantile would occur an average of only 10% of the time. In each case, except the 9312, F is not significant, so the hypothesis of no variation of the type discussed with respect to manufacturer is retained. The F statistic for the 9312 JAN PARTS (involving only the manufacturers National Semiconductor, and Advanced Micro Devices) is extremely large indicating gross differences in parameter distributions. To find out which parameters caused these differences, suspect parameters were removed from the F-test until those remaining would pass the F-test at the .90 level (parameters most suspect are those with the largest difference in their Z statistic when calculated for both manufacturers). The parameters removed were the IIL, IIH, II, and seven of the twelve TPD parameters. The Z-statistics for each of these parameters differed most between the two manufacturers. The remaining eleven parameters passed the F-test with an F value of 3.10 (for $V_1 = 1$, $V_2 = 9$, the .90 quantile of the F-distribution is 3.36).

TABLE 2-III. F-VALUES FOR TESTING VARIATIONS DUE TO MANUFACTURER FOR 883B PARTS

| Part Number | Parameters for F - Distribution $V_1$, $V_2$ | F Value | 0.90 Quantile of F Distribution |
|---|---|---|---|
| 5410 | 5, 50 | 1.80 | *1.975 |
| 54S10 | 1, 10 | 1.85 | 3.29 |
| 5472 | 2, 28 | 0.26 | 2.50 |
| 9312 | 2, 12 | 1.38 | 3.18 |

*Values were interpolated from tables in [2].

As in Table 2-II, no F-value exceeds the 0.90 quantile of the corresponding F-distribution. Indeed, the F-values are insignificantly small except for possibly the 5410 value. This value does not, however warrant rejection of the hypothesis of no variation with respect to manufacturer.

## Comparison of Parameter Distributions

Table 2-IV contains the sample mean ($\bar{X}$) and standard deviation (S) for comparing distributions of parameters for all manufacturers from whom part lots were procured at the JAN, 883B, and/or COMM levels and tested to JAN test specifications. In general, when sample means are "close" and within the limits given in the test specification but one lot shows a smaller standard deviation, then that lot has out-performed the other lot (or lots) with respect to the particular parameter in question. This is true because the lot with the smaller standard deviation will have, on the average, a higher percent of values within the specified limits. Figure 2-2 using symmetric distributions illustrates this concept.

Table 2-IV shows that except for the ITT, SIG, and TI 5410's, the TI 5472's, and the AMD 9312's, the majority of parameters on the 883B device out-perform their COMM counterparts.

The distributions for JAN parts generally have smaller standard deviations than both COMM and 883B parts thus showing greater control in the manufacturing processes used for JAN parts.

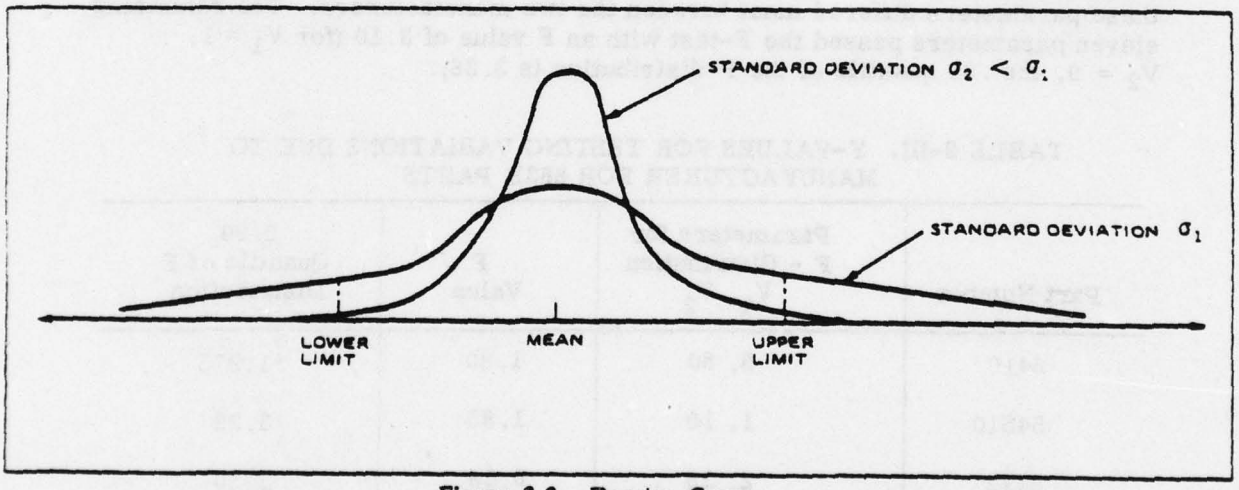



Figure 2-2. Density Curves

## TABLE 2-IV. VARIATION OF PARAMETER DISTRIBUTION COMPARISON

| Manufacturer | Part No. | Test No.* (Parameter) | JAN $\bar{X}$ | JAN S | 883B $\bar{X}$ | 883B S | COMM $\bar{X}$ | COMM S |
|---|---|---|---|---|---|---|---|---|
| Fairchild | 5410 | 101 | -0.9857 | 6.902(-3) | -1.01 | 1.38(-2) | -0.9854 | 1.229(-2) |
| | | 201 | 2.714 | 2.006(-2) | 2.68 | 2.02(-2) | 2.68 | 6.24(-2) |
| | | 301 | 2.678(-1) | 1.09(-2) | 2.74(-1) | 1.76(-2) | 2.761(-1) | 2.566(-2) |
| | | 401 | 5.87(-6) | 1.46(-6) | 1.97(-6) | 1.64(-6) | 3.83(-6) | 1.94(-6) |
| | | 501 | -1.08(-3) | 4.32(-5) | -1.11(-3) | 5.79(-5) | -1.13(-3) | 8.24(-5) |
| | | 601 | 9.17(-6) | 2.77(-6) | 6.01(-7) | 2.62(-6) | 2.7(-6) | 4.51(-6) |
| | | 701 | -3.24(-2) | 7.62(-4) | -3.24(-2) | 1.43(-3) | -3.27(-2) | 1.79(-3) |
| | | 801 | 3.5(-3) | 1.39(-4) | 3.59(-3) | 1.79(-4) | 3.65(-3) | 2.92(-4) |
| | | 901 | 1.07(-2) | 3.99(-4) | 1.07(-2) | 5.95(-4) | 1.1(-2) | 9.26(-4) |
| | | 1101 | 1.22(-8) | 5.93(-10) | 1.26(-8) | 7.42(-10) | 1.24(-8) | 8.33(-10) |
| | | 1201 | 1.22(-8) | 1.30(-9) | 1.37(-8) | 9.97(-10) | 1.32(-8) | 7.88(-10) |
| ITT | 5410 | 101 | -1.06 | 2.68(-2) | -1.12 | 8.46(-2) | -1.09 | 7.37(-2) |
| | | 201 | 2.66 | 2.06(-2) | 2.70 | 8.33(-2) | 2.65 | 5.15(-2) |
| | | 301 | 2.39(-1) | 1.88(-2) | 2.28(-1) | 8.31(-2) | 2.18(-1) | 2.08(-2) |
| | | 401 | 4.10(-6) | 2.20(-6) | 1.61(-5) | 7.19(-6) | 2.97(-6) | 2.3(-6) |
| | | 501 | -1.03(-3) | 7.78(-5) | -1.08(-3) | 9.2(-5) | -9.53(-4) | 1.18(-4) |
| | | 601 | 3.35(-6) | 4.98(-6) | 2.26(-5) | 1.23(-5) | 2.42(-6) | 5.12(-6) |
| | | 701 | -3.05(-2) | 1.71(-3) | -3.17(-2) | 2.52(-3) | -2.88(-2) | 1.58(-3) |
| | | 801 | 3.36(-3) | 2.71(-4) | 3.42(-3) | 3.01(-4) | 3.11(-3) | 3.99(-4) |
| | | 901 | 1.04(-2) | 7.43(-4) | 1.07(-2) | 9.08(-4) | 9.61(-3) | 1.09(-3) |
| | | 1101 | 1.37(-8) | 8.73(-10) | 1.39(-8) | 1.04(-9) | 1.14(-8) | 9.83(-10) |
| | | 1201 | 1.43(-8) | 1.09(-9) | 1.28(-8) | 1.77(-9) | 1.45(-8) | 7.50(-10) |
| Motorola | 5410 | 101 | -1.18 | 7.81(-2) | -1.18 | 8.02(-2) | -1.22 | 2.91(-1) |
| | | 201 | 2.62 | 2.39(-2) | 2.63 | 2.67(-2) | 2.57 | 8.11(-2) |
| | | 301 | 2.78(-1) | 2.51(-2) | 2.73(-1) | 2.65(-2) | 3.61(-1) | 1.28(-1) |
| | | 401 | 3.8(-6) | 1.57(-6) | 4.35(-6) | 2.51(-6) | 3.99(-6) | 1.84(-6) |
| | | 501 | -1.16(-3) | 7.24(-5) | -1.17(-3) | 6.25(-5) | -1.02(-3) | 7.2(-5) |
| | | 601 | 1.25(-6) | 3.31(-6) | 1.83(-6) | 4.06(-6) | 1.96(-4) | 4.41(-6) |
| | | 701 | -3.57(-2) | 4.09(-3) | -3.62(-2) | 4.57(-3) | -3.74(-2) | 2.13(-3) |
| | | 801 | 3.76(-3) | 2.45(-4) | 3.76(-3) | 2.03(-4) | 3.31(-3) | 2.33(-4) |
| | | 901 | 1.17(-2) | 6.91(-4) | 1.18(-2) | 5.67(-4) | 1.03(-2) | 6.59(-4) |
| | | 1101 | 1.16(-8) | 5.93(-10) | 1.10(-8) | 7.83(-10) | 1.26(-8) | 1.02(-9) |
| | | 1201 | 1.35(-8) | 9.27(-10) | 1.25(-8) | 7.92(-10) | 1.68(-8) | 2.07(-9) |
| National | 5410 | 101 | -9.85(-1) | 3.11(-2) | -1.06 | 1.09(-1) | -9.98(-1) | 6.57(-2) |
| | | 201 | 2.63 | 2.41(-2) | 2.62 | 2.51(-2) | 2.66 | 4.48(-2) |
| | | 301 | 2.29(-1) | 2.31(-2) | 2.29(-1) | 1.46(-2) | 2.19(-1) | 2.72(-2) |
| | | 401 | 2.73(-6) | 1.44(-6) | 2.04(-6) | 1.05(-6) | 5.16(-6) | 2.81(-6) |
| | | 501 | -1.07(-3) | 8.4(-5) | -1.15(-3) | 1.20(-4) | -1.13(-3) | 5.28(-4) |
| | | 601 | 1.22(-6) | 3.27(-6) | 4.05(-7) | 2.44(-6) | 6.42(-6) | 6.47(-6) |
| | | 701 | -3.32(-2) | 2.68(-3) | -3.45(-2) | 1.96(-3) | -3.46(-2) | 2.38(-3) |
| | | 801 | 3.47(-3) | 2.81(-4) | 3.73(-3) | 3.90(-4) | 3.49(-3) | 2.04(-4) |
| | | 901 | 1.06(-2) | 8.1(-4) | 1.13(-2) | 1.05(-3) | 1.07(-2) | 5.91(-4) |
| | | 1101 | 1.21(-8) | 9.85(-10) | 1.13(-8) | 9.08(-10) | 1.13(-8) | 1.11(-9) |
| | | 1201 | 1.31(-8) | 1.49(-9) | 1.21(-8) | 8.62(-10) | 1.15(-8) | 8.95(-10) |
| Signetics | 5410 | 101 | -8.54(-1) | 1.68(-2) | -8.49(-1) | 9.63(-3) | -8.63(-1) | 1.24(-2) |
| | | 201 | 3.26 | 1.39(-2) | 3.17 | 2.32(-2) | 3.15 | 9.35(-3) |
| | | 301 | 2.43(-1) | 2.3(-2) | 2.41(-1) | 1.71(-2) | 2.91(-1) | 2.74(-2) |
| | | 401 | 2.58(-6) | 6.98(-7) | 4.61(-6) | 1.91(-6) | 1.96(-6) | 9.16(-7) |
| | | 501 | -1.08(-3) | 6.11(-5) | -1.07(-3) | 5.87(-5) | -1.13(-3) | 4.75(-5) |
| | | 601 | 1.48(-6) | 3.56(-6) | 3.27(-6) | 4.91(-6) | 3.5(-7) | 3.75(-6) |
| | | 701 | -3.17(-2) | 9.77(-4) | -3.42(-2) | 1.26(-3) | -3.23(-2) | 1.34(-3) |
| | | 801 | 3.48(-3) | 2.04(-4) | 3.48(-3) | 2.13(-4) | 3.70(-3) | 1.6(-4) |
| | | 901 | 1.06(-2) | 5.45(-4) | 1.07(-2) | 6.0(-4) | 1.09(-1) | 4.38(-4) |
| | | 1101 | 1.29(-8) | 5.24(-10) | 1.26(-8) | 5.92(-10) | 1.17(-8) | 5.36(-10) |
| | | 1201 | 1.30(-8) | 8.61(-10) | 1.24(-8) | 9.07(-10) | 1.25(-8) | 9.02(-10) |
| Texas Instruments | 5410 | 101 | -9.08(-1) | 3.05(-2) | -9.41(-1) | 2.82(-2) | -9.25(-1) | 2.58(-2) |
| | | 201 | 2.63 | 2.55(-2) | 2.62 | 2.98(-2) | 2.61 | 1.77(-2) |
| | | 301 | 3.04(-1) | 2.42(-2) | 2.64(-1) | 1.32(-2) | 2.98(-1) | 1.68(-2) |
| | | 401 | 2.54(-6) | 1.77(-6) | 2.14(-6) | 5.59(-7) | 1.56(-6) | 4.0(-7) |
| | | 501 | -1.18(-3) | 5.67(-5) | -1.15(-3) | 4.47(-5) | -1.21(-3) | 3.02(-5) |

*Refer to Appendix I tables A-III and AV for definition.

## TABLE 2-IV. VARIATION OF PARAMETER DISTRIBUTION COMPARISON (Continued)

| Manufacturer | Part No. | Test No.* (Parameter) | JAN $\bar{X}$ | JAN S | 883B $\bar{X}$ | 883B S | COMM $\bar{X}$ | COMM S |
|---|---|---|---|---|---|---|---|---|
| Texas Instruments (Continued) | 5410 | 601 | 3.46(-7) | 1.83(-6) | 0.0 | 0.0 | 0.0 | 0.0 |
| | | 701 | -3.38(-2) | 1.35(-3) | -3.55(-2) | 8.87(-4) | -3.48(-2) | 7.26(-4) |
| | | 801 | 3.75(-3) | 1.81(-4) | 3.70(-3) | 1.42(-4) | 3.89(-3) | 9.36(-5) |
| | | 901 | 1.19(-2) | 6.29(-4) | 1.19(-2) | 4.98(-4) | 1.25(-1) | 3.31(-4) |
| | | 1101 | 1.1(-8) | 7.51(-10) | 1.03(-8) | 6.46(-10) | 1.22(-8) | 4.80(-10) |
| | | 1201 | 1.3(-8) | 7.58(-10) | 1.23(-8) | 6.69(-10) | 1.35(-8) | 8.55(-10) |
| National | 5472 | 1 | 3.03 | 3.1(-2) | 3.03 | 5.11(-2) | 2.98 | 4.05(-2) |
| | | 5 | 2.88(-1) | 7.1(-2) | 2.81(-1) | 5.28(-2) | 2.8(-1) | 5.09(-2) |
| | | 9 | -1.08 | 2.79(-1) | -0.92(-1) | 2.26(-1) | -1.02 | 2.70(-1) |
| | | 18 | -9.96(-4) | 8.75(-5) | -8.79(-4) | 1.21(-4) | -1.04(-3) | 1.44(-4) |
| | | 24 | -2.18(-3) | 1.97(-4) | -2.14(-3) | 2.56(-4) | -2.29(-3) | 2.6(-4) |
| | | 26 | -2.02(-3) | 1.81(-4) | -1.99(-3) | 2.38(-4) | -2.25(-3) | 9.69(-4) |
| | | 28 | 2.06(-6) | 1.1(-6) | 2.2(-6) | 1.73(-6) | 1.65(-6) | 9.23(-7) |
| | | 34 | 3.21(-6) | 3.97(-6) | 3.3(-6) | 3.63(-6) | 2.46(-6) | 1.59(-6) |
| | | 40 | 1.03(-5) | 2.65(-6) | 1.09(-5) | 6.25(-6) | 7.1(-6) | 1.14(-5) |
| | | 42 | 1.65(-5) | 5.81(-6) | 1.74(-5) | 1.09(-5) | 1.3(-5) | 5.4(-6) |
| | | 46 | -5.97(-4) | 1.08(-4) | -5.81(-4) | 1.20(-4) | -6.2(-4) | 1.48(-4) |
| | | 48 | -3.46(-2) | 1.82(-3) | -3.39(-2) | 1.83(-3) | -3.42(-2) | 3.27(-3) |
| | | 50 | 1.30(-2) | 1.18(-3) | 1.28(-2) | 1.51(-3) | 1.37(-2) | 1.59(-3) |
| | | 95 | 1.14(-8) | 9.88(-10) | 1.26(-8) | 1.01(-9) | 1.17(-8) | 1.59(-9) |
| | | 97 | 2.36(-8) | 1.48(-9) | 2.49(-8) | 1.88(-9) | 2.57(-8) | 1.99(-9) |
| | | 99 | 1.34(-8) | 8.97(-10) | 1.46(-8) | 1.05(-9) | 1.43(-8) | 8.8(-10) |
| | | 101 | 2.19(-8) | 1.81(-9) | 2.33(-8) | 1.64(-9) | 2.29(-8) | 1.88(-9) |
| Signetics | 5472 | 1 | 3.13 | 1.65(-2) | 3.11 | 2.49(-2) | 3.15 | 1.95(-2) |
| | | 5 | 2.44(-1) | 5.05(-2) | 2.69(-1) | 4.66(-2) | 2.61(-1) | 4.73(-2) |
| | | 9 | -8.49(-1) | 2.81(-2) | -8.57(-1) | 2.05(-2) | -8.4(-1) | 3.46(-2) |
| | | 18 | -1.11(-3) | 5.21(-5) | -1.06(-3) | 5.01(-5) | -1.06(-3) | 5.93(-5) |
| | | 24 | -2.41(-3) | 1.09(-4) | -2.29(-3) | 1.19(-4) | -2.27(-3) | 1.29(-4) |
| | | 26 | -2.25(-3) | 1.06(-4) | -2.12(-3) | 1.02(-4) | -2.11(-3) | 1.06(-4) |
| | | 28 | 3.18(-6) | 8.18(-7) | 2.37(-6) | 1.48(-6) | 2.74(-6) | 6.24(-6) |
| | | 34 | 4.49(-6) | 3.24(-6) | 3.23(-6) | 2.06(-6) | 4.15(-6) | 2.99(-6) |
| | | 40 | 1.40(-5) | 3.07(-6) | 9.97(-6) | 5.16(-6) | 1.23(-5) | 7.2(-6) |
| | | 42 | 1.33(-5) | 5.89(-6) | 9.57(-6) | 8.48(-6) | 1.26(-5) | 1.04(-5) |
| | | 46 | -7.14(-4) | 4.78(-5) | -6.4(-4) | 1.55(-4) | -6.54(-4) | 1.04(-4) |
| | | 48 | -3.38(-2) | 1.35(-3) | -3.31(-2) | 1.25(-3) | -3.31(-2) | 1.14(-3) |
| | | 50 | 1.35(-2) | 5.83(-4) | 1.28(-2) | 6.64(-4) | 1.28(-2) | 5.91(-4) |
| | | 95 | 1.1(-8) | 8.79(-10) | 1.11(-8) | 9.12(-10) | 1.07(-8) | 1.60(-9) |
| | | 97 | 2.34(-8) | 1.32(-9) | 2.5(-8) | 1.60(-9) | 2.41(-8) | 1.12(-9) |
| | | 99 | 1.34(-8) | 7.43(-10) | 1.35(-8) | 6.68(-10) | 1.40(-8) | 1.07(-9) |
| | | 101 | 2.23(-8) | 1.23(-9) | 2.35(-8) | 1.68(-9) | 2.27(-8) | 1.25(-9) |
| Texas Instruments | 5472 | 1 | 2.98 | 2.9(-2) | 2.98 | 1.06(-1) | 2.97 | 4.32(-2) |
| | | 5 | 2.78(-1) | 1.97(-2) | 3.3(-1) | 7.5(-2) | 3.14(-1) | 4.89(-2) |
| | | 9 | -6.71(-1) | 3.5(-2) | – | – | – | – |
| | | 18 | -1.2(-3) | 7.99(-5) | -9.79(-4) | 7.78(-5) | -8.92(-4) | 3.51(-4) |
| | | 24 | -2.21(-3) | 1.52(-4) | -2.02(-3) | 1.23(-3) | -1.62(-3) | 1.65(-4) |
| | | 26 | -1.2(-3) | 8.22(-5) | -1.19(-3) | 1.24(-3) | -8.03(-4) | 4.29(-4) |
| | | 28 | 1.78(-6) | 7.3(-7) | 8.87(-7) | 4.61(-7) | 8.52(-7) | 4.14(-6) |
| | | 34 | 2.52(-6) | 1.06(-6) | 1.27(-6) | 6.50(-7) | 1.57(-6) | 4.08(-6) |
| | | 40 | -6.12(-4) | 5.66(-5) | -4.89(-4) | 1.18(-4) | -4.57(-4) | 4.31(-5) |
| | | 42 | 1.30(-5) | 4.39(-6) | 5.36(-6) | 2.83(-6) | 5.96(-6) | 1.92(-6) |
| | | 46 | -4.48(-4) | 4.74(-5) | -3.72(-4) | 7.27(-5) | -3.44(-4) | 3.24(-5) |
| | | 48 | -3.78(-2) | 1.99(-3) | -3.59(-2) | 2.01(-3) | -3.21(-2) | 2.42(-3) |
| | | 50 | 1.38(-2) | 9.08(-4) | 1.13(-2) | 9.83(-4) | 1.01(-2) | 1.18(-3) |
| | | 95 | 1.01(-8) | 9.29(-10) | 1.08(-8) | 1.04(-9) | 1.14(-8) | 1.07(-9) |
| | | 97 | 2.31(-8) | 1.45(-9) | 2.45(-8) | 1.8(-9) | 2.45(-8) | 1.71(-9) |
| | | 99 | 1.28(-8) | 6.35(-10) | 1.29(-8) | 6.81(-10) | 1.37(-8) | 6.74(-10) |
| | | 101 | 2.23(-8) | 1.64(-9) | 2.34(-8) | 1.75(-9) | 2.47(-8) | 1.94(-9) |
| Advanced Micro Devices | 9312 | 201 | 3.03 | 2.46(-2) | 3.0 | 3.09(-2) | 3.0 | 2.09(-2) |
| | | 301 | 2.53(-1) | 1.77(-2) | 3.03(-1) | 3.40(-2) | 2.79(-1) | 3.42(-2) |
| | | 101 | -1.03 | 4.95(-2) | -1.04 | 6.11(-2) | -9.35(-1) | 4.36(-2) |
| | | 301 | -1.12(-3) | 6.53(-5) | -8.23(-4) | 4.43(-4) | -7.66(-4) | 4.84(-4) |

## TABLE 2-IV. VARIATION OF PARAMETER DISTRIBUTION COMPARISON (Continued)

| Manufacturer | Part No. | Test No.* (Parameter) | JAN $\bar{X}$ | JAN S | 883B $\bar{X}$ | 883B S | COMM $\bar{X}$ | COMM S |
|---|---|---|---|---|---|---|---|---|
| Advanced Micro Devices (Continued) | 9312 | 401 | 3.67(-6) | 2.03(-6) | 1.98(-6) | 1.94(-6) | 2.54(-6) | 4.75(-6) |
| | | 601 | 5.54(-6) | 3.35(-6) | 2.95(-6) | 2.49(-6) | 3.74(-6) | 2.52(-6) |
| | | 701 | -8.25(-2) | 1.46(-3) | -7.79(-2) | 5.44(-3) | -8.13(-2) | 1.81(-3) |
| | | 801 | 3.05(-2) | 1.53(-3) | 3.05(-2) | 1.91(-3) | 3.18(-2) | 2.1(-3) |
| | | 1201 | 1.77(-8) | 1.08(-9) | 2.12(-8) | 1.31(-9) | 2.14(-8) | 1.24(-9) |
| | | 1301 | 1.62(-8) | 1.03(-9) | 1.81(-8) | 1.04(-9) | 1.90(-8) | 8.3(-10) |
| | | 1401 | 2.71(-8) | 1.41(-9) | 3.09(-8) | 1.62(-9) | 3.17(-8) | 1.31(-9) |
| | | 1501 | 2.39(-8) | 1.36(-9) | 2.66(-8) | 1.56(-9) | 2.79(-8) | 1.32(-9) |
| | | 1601 | 1.68(-8) | 1.0(-9) | 1.96(-8) | 1.21(-9) | 2.0(-8) | 1.04(-9) |
| | | 1701 | 1.09(-8) | 6.66(-10) | 1.27(-8) | 7.78(-10) | 1.32(-8) | 5.86(-10) |
| | | 1801 | 2.16(-8) | 1.13(-9) | 2.53(-8) | 1.50(-9) | 2.58(-8) | 1.38(-9) |
| | | 1901 | 2.27(-8) | 1.28(-9) | 2.46(-8) | 1.46(-9) | 2.60(-8) | 1.16(-9) |
| | | 2001 | 9.34(-9) | 1.02(-9) | 1.25(-8) | 1.17(-9) | 1.24(-8) | 1.22(-9) |
| | | 2101 | 8.32(-9) | 8.57(-10) | 9.31(-9) | 7.6(-10) | 9.79(-9) | 7.96(-10) |
| | | 2201 | 1.85(-8) | 1.08(-9) | 2.15(-8) | 1.33(-9) | 2.19(-8) | 1.2(-9) |
| | | 2301 | 1.56(-8) | 1.31(-9) | 1.80(-8) | 1.54(-9) | 1.90(-8) | 1.43(-9) |
| Motorola | 9312 | 201 | 3.1 | 2.66(-1) | 3.06 | 2.18(-2) | 3.04 | 1.81(-1) |
| | | 301 | 3.15(-1) | 2.83(-2) | 2.83(-1) | 2.73(-2) | 3.07(-1) | 2.55(-2) |
| | | 101 | -1.05 | 4.67(-2) | -1.03 | 3.85(-2) | -1.04 | 3.1(-2) |
| | | 501 | -9.13(-4) | 3.59(-4) | -9.46(-4) | 2.58(-4) | -9.81(-4) | 1.06(-4) |
| | | 401 | 1.38(-5) | 5.42(-6) | 1.41(-5) | 4.54(-6) | 1.14(-5) | 5.19(-6) |
| | | 601 | 1.77(-5) | 7.46(-6) | 1.83(-5) | 6.27(-6) | 1.48(-5) | 6.84(-6) |
| | | 701 | -7.67(-2) | 2.47(-3) | -8.22(-2) | 2.69(-3) | -7.69(-2) | 5.28(-3) |
| | | 801 | 3.1(-2) | 2.4(-3) | 2.92(-2) | 1.67(-3) | 2.82(-2) | 1.66(-3) |
| | | 1201 | 2.41(-8) | 1.3(-9) | 2.36(-8) | 1.02(-9) | 2.84(-8) | 1.6(-9) |
| | | 1301 | 2.09(-8) | 1.15(-9) | 2.01(-8) | 7.1(-10) | 2.38(-8) | 1.06(-9) |
| | | 1401 | 3.42(-8) | 1.45(-9) | 3.34(-8) | 8.56(-10) | 3.73(-8) | 1.44(-9) |
| | | 1501 | 3.0(-8) | 1.58(-9) | 2.93(-8) | 1.11(-9) | 3.4(-8) | 1.74(-9) |
| | | 1601 | 2.25(-8) | 1.58(-9) | 2.19(-8) | 1.48(-9) | 2.65(-8) | 1.86(-9) |
| | | 1701 | 1.36(-8) | 6.96(-10) | 1.28(-8) | 4.24(-10) | 1.66(-8) | 6.82(-10) |
| | | 1801 | 2.67(-8) | 1.15(-9) | 2.58(-8) | 8.49(-10) | 2.99(-8) | 1.33(-9) |
| | | 1901 | 2.8(-8) | 1.85(-9) | 2.72(-8) | 1.73(-9) | 3.18(-8) | 2.1(-9) |
| | | 2001 | 1.38(-8) | 1.52(-9) | 1.31(-8) | 1.08(-9) | 1.75(-8) | 1.37(-9) |
| | | 2101 | 1.0(-8) | 9.75(-10) | 9.21(-9) | 7.52(-10) | 1.23(-8) | 5.73(-10) |
| | | 2201 | 2.25(-8) | 9.79(-10) | 2.16(-8) | 7.65(-10) | 2.55(-8) | 9.33(-10) |
| | | 2301 | 1.96(-8) | 1.51(-9) | 1.89(-8) | 1.21(-9) | 2.38(-8) | 1.62(-9) |
| Fairchild | 9312 | 201 | | | 2.99 | 2.64(-2) | 3.03 | 4.94(-2) |
| | | 301 | | | 2.77(-1) | 1.85(-2) | 2.73(-1) | 1.71(-2) |
| | | 101 | | | -1.04 | 4.26(-2) | -9.82(-1) | 2.82(-2) |
| | | 501 | | | -1.06(-3) | 7.26(-5) | -1.07(-3) | 9.26(-5) |
| | | 401 | | | 5.82(-6) | 6.91(-6) | 9.97(-6) | 6.15(-6) |
| | | 601 | | | 7.62(-6) | 2.64(-5) | 1.25(-5) | 1.98(-5) |
| | | 701 | | | -4.77(-2) | 3.69(-3) | -5.33(-2) | 3.21(-3) |
| | | 801 | | | 2.97(-2) | 1.62(-3) | 2.98(-2) | 2.3(-3) |
| | | 1201 | | | 2.02(-8) | 6.37(-10) | 1.82(-8) | 1.01(-9) |
| | | 1301 | | | 1.87(-8) | 7.66(-10) | 1.63(-8) | 1.05(-9) |
| | | 1401 | | | 3.14(-8) | 1.03(-9) | 2.83(-8) | 1.57(-9) |
| | | 1501 | | | 2.63(-8) | 8.27(-10) | 2.39(-8) | 1.27(-9) |
| | | 1601 | | | 1.80(-8) | 5.18(-10) | 1.68(-8) | 7.18(-10) |
| | | 1701 | | | 1.62(-8) | 7.10(-10) | 1.39(-8) | 9.93(-10) |
| | | 1801 | | | 2.87(-8) | 9.75(-10) | 2.56(-8) | 1.63(-9) |
| | | 1901 | | | 2.35(-8) | 6.95(-10) | 2.22(-8) | 9.56(-10) |
| | | 2001 | | | 1.37(-8) | 9.13(-10) | 1.38(-8) | 1.08(-9) |
| | | 2101 | | | 1.25(-8) | 7.1(-10) | 1.05(-8) | 7.19(-10) |
| | | 2201 | | | 2.48(-8) | 7.83(-10) | 2.19(-8) | 1.18(-9) |
| | | 2301 | | | 2.19(-8) | 1.10(-9) | 1.98(-8) | 1.37(-9) |

Note: $1.98(-8) = 1.98 \times 10^{-8}$

## Compliance to Specification

The measure we use to determine if a lot of parts complies to a certain test specification is the fraction defective of the lot with respect to the particular test specification. Table 2-V lists, for each code, 90% confidence bounds on the probability of defective part based on the observed fraction defective. These bounds are calculated by the following formulas which utilize the normal approximation to the binominal distribution. Here, $\hat{p}$ = observed fraction defective, $Z = 1.64485$ (i.e. Z is the 0.95 quantile of the normal distribution with 0 mean and unit variance), and n is the sample size. For $0 < \hat{p} < 1$, we have

$$\hat{p}_u = \text{upper limit} = \frac{\hat{p} + \frac{Z^2}{2n} + (Z/\sqrt{n})\sqrt{\hat{p}\,(1-\hat{p}) + Z^2/4n}}{1 + Z^2/n}$$

$$\hat{p}_L = \text{lower limit} = \frac{\hat{p} + \frac{Z^2}{2n} - (Z/\sqrt{n})\sqrt{\hat{p}\,(1-\hat{p}) + Z^2/4n}}{1 + Z^2/n}$$

(See [4].)

When

$$\hat{p} = 0 ,$$

we take (see [5])

$$p_L = 0$$

$$p_u = 1 - (0.10)^{1/n}$$

and when

$$\hat{p} = 1 ,$$

$$p_L = (0.10)^{1/n}$$

$$p_u = 1 .$$

Compliance to specifications can thus be determined by examining Table 2-V. Obviously, confidence bounds indicating a low value for the true probability of a defective part show a high tendency to comply to specifications.

## SAMPLE CALCULATIONS OF GUARDBAND LIMITS

In this first example, it is desired to avoid testing an ICC parameter on a TI 54S10 device procured to 883B at 125°C. It is desired that this parameter pass the JAN test specification. From Table A-1 in Appendix 1, code 22-4 satisfies these requirements.

From the code 22-4 the printouts summarizing the regression analyses are found in Appendix 2. From Appendix 1 we see that parameter sequence number 8 corresponds to an ICC parameter. The correlation for the (EXP) model is 0.9955 while RBAR is 0.01524. This combination is seen to be better than the corresponding combinations for the (LIN) and (LLIN) models. Hence, the (EXP) model is selected.

The predictive equation is

$$Y = e^{45.82X - 4.874}$$

or

$$X = \frac{\ln Y + 4.874}{45.82}$$

For the MIL test specification, the ICC parameter measured at 125°C must be no larger than 0.027. Substituting this value for Y results in X = 0.0275. Hence, if we take 0.0275 as the upper limit imposed at 25°C and this limit is satisfied, then we can be confident that the measurement at 125°C will be below 0.027.

It should be pointed out that the MIL test specification for ICC gives 0.027 as an upper limit at 25°C also. Since our guardband limit is larger than this, we may retain 0.027 as the limit to be imposed at 25°C since it is presumed that the device must also pass the test specification at 25°C.

As a second example, take code 4-14. This has:

Device - 5410

Man. - Signetics

Procured - 883B

Tested to - JAN

We take Y to be the IIH (Input high current) parameter at 125°C.

The regression analysis shows that for parameter sequence number 3 (IIH parameter) the (LLIN) model fits best with correlation 0.9907 and RBAR = 0.0186. The predictive equation is

$$Y = (e^{-0.1103}) X^{0.9580} = 0.8956 X^{0.9580}$$

or

$$X = 1.122 Y^{1.0438}$$

The MIL specification calls for an upper limit on this parameter at 125°C of 0.00004. Substituting this for Y gives

$$X = (1.122) (0.00004)^{1.0438} = 0.0000288$$

So, we impose 0.0000288 as an upper limit at 25°C for this parameter to insure a measured value less than 0.00004 at 125°C.

An an example of an IIL parameter, we take

Code - 19-3

Device - 9312

Man. - AMD

Procured - 883B

Tested to - COMM

We take Y to be the IIL parameter measurement at -55°C.

The IIL parameter corresponds to parameter sequence number 3. The predictive equation is

$$Y = 1.57X + 0.0006642$$

or

$$X = (Y - 0.0006642)/1.57$$

(the (LIN) model was the best fit with correlation 0.9731 and RBAR = 0.0532). The lower limit specified at -55°C is -0.0016. Substituting this value for Y gives X = -0.00144. Hence, if a lower limit of -0.00144 is satisfied at 25°C, we can be confident that the lower limit of -0.0016 will be satisfied at -55°C.

## TABLE 2-V. 90% CONFIDENCE INTERVALS FOR THE PROBABILITY OF DEFECTIVE PART

| *Code | 25°C | | 125°C | | -55°C | | Sample Size |
|---|---|---|---|---|---|---|---|
| | $P_L$ | $P_U$ | $P_L$ | $P_U$ | $P_L$ | $P_U$ | |
| 1-1 | 0.0 | 0.0209 | 0.0 | 0.0209 | 0.0020 | 0.0401 | 109 |
| 1-2 | 0.0 | 0.0223 | 0.0022 | 0.0428 | 0.0 | 0.0223 | 102 |
| 2-1 | 0.0061 | 0.0539 | 0.0 | 0.0209 | 0.0061 | 0.0539 | 109 |
| 2-2 | 0.0060 | 0.0535 | 0.0 | 0.0207 | 0.0 | 0.0207 | 110 |
| 3-8 | 0.0 | 0.0213 | 0.0 | 0.0213 | 0.0 | 0.0213 | 107 |
| 3-9 | 0.0 | 0.0223 | 0.0022 | 0.0428 | 0.0 | 0.0223 | 102 |
| 4-1 | 0.0113 | 0.0681 | 0.0062 | 0.0549 | 0.0113 | 0.0681 | 107 |
| 4-2 | 0.0020 | 0.0401 | 0.0020 | 0.0401 | 0.0061 | 0.0539 | 109 |
| 4-3 | 0.0043 | 0.0817 | 0.0 | 0.0433 | 0.0043 | 0.0817 | 52 |
| 4-4 | 0.0 | 0.0213 | 0.0 | 0.0213 | 0.0 | 0.0213 | 107 |
| 4-5 | 0.0169 | 0.0807 | 0.1490 | 0.2767 | 0.0062 | 0.0549 | 107 |
| 4-6 | 0.0 | 0.0410 | 0.0 | 0.0410 | 0.0 | 0.0110 | 55 |
| 4-7 | 0.0021 | 0.0404 | 0.0021 | 0.0404 | 0.0021 | 0.0401 | 108 |
| 4-8 | 0.0029 | 0.0568 | 0.0029 | 0.0568 | 0.0029 | 0.0568 | 76 |
| 4-9 | 0.0 | 0.0410 | 0.0121 | 0.1041 | 0.0121 | 0.1041 | 55 |
| 4-10 | 0.0020 | 0.0397 | 0.0020 | 0.0397 | 0.0060 | 0.0535 | 110 |
| 4-11 | 0.0 | 0.0213 | 0.0021 | 0.0408 | 0.0062 | 0.0549 | 107 |
| 4-12 | 0.0042 | 0.0803 | 0.0 | 0.0425 | 0.0042 | 0.0803 | 53 |
| 4-13 | 0.0021 | 0.0404 | 0.0 | 0.0211 | 0.0021 | 0.0404 | 108 |
| 4-14 | 0.0 | 0.0207 | 0.0020 | 0.0397 | 0.0161 | 0.0786 | 110 |
| 4-15 | 0.0041 | 0.0775 | 0.0121 | 0.1041 | 0.0121 | 0.1041 | 55 |
| 4-16 | 0.0020 | 0.0397 | 0.0 | 0.0207 | 0.0020 | 0.0397 | 110 |
| 4-17 | 0.0 | 0.0213 | 0.0 | 0.0213 | 0.0 | 0.0213 | 107 |
| 4-18 | 0.0 | 0.0410 | 0.0041 | 0.0775 | 0.0041 | 0.0775 | 55 |
| 5-1 | 0.0043 | 0.0817 | 0.0 | 0.0433 | 0.0 | 0.0133 | 52 |
| 5-2 | 0.0 | 0.0410 | 0.0041 | 0.0775 | 0.0121 | 0.1041 | 55 |
| 6-1 | 0.0 | 0.0209 | 0.0020 | 0.0401 | 0.0 | 0.0209 | 109 |
| 6-2 | 0.0996 | 0.2111 | 0.0061 | 0.0539 | 0.0166 | 0.0793 | 109 |
| 7-1 | 0.0 | 0.0207 | 0.0 | 0.0207 | 0.0 | 0.0207 | 110 |
| 7-2 | 0.0029 | 0.0561 | 0.0 | 0.0295 | 0.0 | 0.0295 | 77 |
| 8-4 | 0.0021 | 0.0404 | 0.0021 | 0.0404 | 0.0061 | 0.0514 | 108 |
| 8-5 | 0.0 | 0.0207 | 0.0 | 0.0207 | 0.0 | 0.0207 | 110 |
| 9-1 | 0.0110 | 0.0663 | 0.0020 | 0.0397 | 0.0 | 0.0207 | 110 |
| 9-2 | 0.0041 | 0.0775 | 0.0220 | 0.1289 | 0.0 | 0.0110 | 55 |
| 9-3 | 0.0021 | 0.0412 | 0.0114 | 0.0687 | 0.0063 | 0.0551 | 106 |

| *Code | 25°C | | 125°C | | -55°C | | Sample Size |
|---|---|---|---|---|---|---|---|
| | $P_L$ | $P_U$ | $P_L$ | $P_U$ | $P_L$ | $P_U$ | |
| 9-4 | 0.0223 | 0.0904 | 0.0285 | 0.1020 | 0.0060 | 0.0535 | 110 |
| 9-5 | 0.0 | 0.0433 | 0.0350 | 0.1607 | 0.0233 | 0.1358 | 52 |
| 9-6 | 0.0 | 0.0209 | 0.0 | 0.0209 | 0.0020 | 0.0401 | 109 |
| 9-8 | 0.0021 | 0.0404 | 0.0112 | 0.0675 | 0.0061 | 0.0544 | 108 |
| 9-9 | 0.0065 | 0.0575 | 0.0177 | 0.0845 | 0.0118 | 0.0713 | 102 |
| 10-1 | 0.0 | 0.0230 | 0.0 | 0.0230 | 0.0067 | 0.0592 | 99 |
| 10-2 | 0.0 | 0.0219 | 0.0 | 0.0219 | 0.0174 | 0.0829 | 104 |
| 11-1 | 0.0063 | 0.0554 | 0.0114 | 0.0687 | 0.0114 | 0.0687 | 106 |
| 11-2 | 0.0062 | 0.0549 | 0.0021 | 0.0408 | 0.0169 | 0.0807 | 107 |
| 12-1 | 0.0171 | 0.0814 | 0.0171 | 0.0814 | 0.0063 | 0.0551 | 106 |
| 12-2 | 0.0020 | 0.0397 | 0.0060 | 0.0535 | 0.0020 | 0.0397 | 110 |
| 12-3 | 0.0020 | 0.0397 | 0.0110 | 0.0663 | 0.0110 | 0.0663 | 110 |
| 12-4 | 0.0112 | 0.0675 | 0.0021 | 0.0404 | 0.0 | 0.0211 | 108 |
| 12-5 | 0.0021 | 0.0404 | 0.0021 | 0.0404 | 0.0061 | 0.0544 | 108 |
| 12-6 | 0.0 | 0.0150 | 0.0133 | 0.1139 | 0.0045 | 0.0848 | 50 |
| 12-7 | 0.0551 | 0.1163 | 0.0 | 0.0207 | 0.0060 | 0.0535 | 110 |
| 12-8 | 0.1927 | 0.3282 | 0.0 | 0.0207 | 0.0020 | 0.0397 | 110 |
| 12-9 | 0.0031 | 0.0591 | 0.0031 | 0.0591 | 0.0 | 0.0310 | 73 |
| 13-1 | 0.0 | 0.0230 | 0.0 | 0.0230 | 0.0183 | 0.0870 | 99 |
| 13-2 | 0.0 | 0.0209 | 0.0 | 0.0209 | 0.0020 | 0.0401 | 109 |
| 14-4 | 0.0 | 0.0217 | 0.0021 | 0.0416 | 0.0 | 0.0217 | 105 |
| 14-5 | 0.0020 | 0.0401 | 0.0 | 0.0209 | 0.0 | 0.0209 | 109 |
| 15-1 | 0.0021 | 0.0408 | 0.0 | 0.0213 | 0.0021 | 0.0408 | 107 |
| 15-2 | 0.0352 | 0.1144 | 0.0020 | 0.0401 | 0.0 | 0.0209 | 109 |
| 16-7 | 0.0021 | 0.0401 | 0.0061 | 0.0544 | 0.0112 | 0.0675 | 108 |
| 16-8 | 0.2611 | 0.1077 | 0.1915 | 0.3310 | 0.2027 | 0.3107 | 109 |
| 17-1 | 0.0 | 0.0207 | 0.0 | 0.0207 | 0.0 | 0.0207 | 110 |
| 17-2 | 0.0 | 0.0207 | 0.0020 | 0.0397 | 0.0 | 0.0207 | 110 |
| 18-1 | 0.0031 | 0.0599 | 0.0252 | 0.1181 | 0.0168 | 0.0998 | 72 |
| 19-1 | 0.0418 | 0.1256 | 0.0020 | 0.0401 | 0.0556 | 0.1476 | 109 |
| 19-3 | 0.0166 | 0.0793 | 0.0111 | 0.0669 | 0.0 | 0.0209 | 109 |
| 22-1 | 0.0020 | 0.0397 | 0.0020 | 0.0397 | 0.0 | 0.0207 | 110 |
| 22-2 | 0.0060 | 0.0535 | 0.0060 | 0.0535 | 0.0060 | 0.0535 | 110 |
| 22-3 | 0.0110 | 0.0663 | 0.0 | 0.0207 | 0.0 | 0.0207 | 110 |
| 22-4 | 0.0020 | 0.0397 | 0.0110 | 0.0663 | 0.0164 | 0.0786 | 110 |

*Refer to Appendix 1 Table A-1 for Definition.

## ANOMALIES

Several problems were discovered during the testing phase of this program. These problems were (1) an error in the 9312 test programs (2) System Timing generator rise time not fast enough to accurately measure propagation delay on Schottky (54S10) parts. While these did present some difficulties, methods of overcoming these problems were found so that a valid data analysis could be done.

The problem with the 9312 programs was an incorrect set-up in the IIL tests for the data inputs on the AMD and Motorola parts. This problem was solved by only doing data analysis on the IIL tests of the select and enable inputs of all parts, and performing data analysis on the IIL tests of all inputs of the Fairchild parts. This problem had no significant impact on the results of the study.

After testing the 54S10 devices, it was found that the failure quantity was very high. The failures were almost entirely attributable to the propagation delay measurements. The failures were due to two factors: (1) the test specification called for an input rise time of 5 nsec or less and the Sentry 610 - 5 MHz pin electronic card rise time is about 20 nsec (2) the switching threshold of the Schottky clamped TTL devices is not equal to the time measurement reference level. Since the time measurements are done at the 1.5 volt level, there is a time difference between the beginning of the measurement and the crossing of the input threshold. With a rise time of 5 nsec, the slope at the 1.5 volt level would be about 2 nsec per volt. If the actual threshold of the device was 1.8 volts, the time measurement error would be (1.8-1.5) X 2 = 0.6 nsec. This amount can be accounted for by a shift in the specified limit. For a 20 nsec rise time, the slope would be about 8 nsec per volt so the error would be 2.4 nsec for the same measurement. The fraction defective analysis was done by ignoring failures due to out of tolerance propagation delay. The guardband analysis was not affected by this problem because a consistent shift in value for a parameter does not prevent curve fitting and calculation of correlation coefficients but only changes the mean.

For the purposes of this study, a functional test is defined as the execution of the truth table of a device using nominal power supply voltage, non-critical timing, worst case input logic levels, worst case output logic level limits, and worst case output loading. Although this test was not required by the vendor and MIL specifications, it was included as an additional verification of device functionality and input logic level limits. The military specification does not always agree with the commercial specification of various vendors for a particular device type. Therefore, it cannot be assumed that the military and commercial functional tests as defined above would be identical. For example, the worst case input logic levels in MIL specifications are often different values at the three temperatures while in the commercial specifications they are the same at all temperatures.

TABLE 2-VI. FAILURE ANALYSIS RESULTS

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| Fairchild | | | | | | |
| (AA) 9N10DM | 0 | 0 | 1 | 3 | 2 | 3 |
| (AB) 9312DM | 0 | 1 | 0 | 2 | 4 | 3 |
| (AD) 9S10DM | 2 | 0 | 2 | 1 | 1 | 0 |
| (AE) 9N10DMQB | 0 | 1 | 0 | 1 | 1 | 2 |
| (AH) 9S10DMQB | 2 | 0 | 0 | 2 | 2 | 2 |
| (AF) 9312DMQB | 0 | 0 | 0 | 1 | 3 | 2 |
| (AJ) JM38510/00103 | | | | 1 | 0 | 1 |
| (AN) JM38510/00104 | | | | 1 | 0 | 0 |
| ITT | | | | | | |
| (BA) ITT5410J | 0 | 1 | 0 | 0 | 0 | 0 |
| (BE) ITT5410J/B2 | TPHL 16 | 2 | 4 | 4 | TPLH IIH 22 | 2 |
| (BJ) JM38510/00103 | | | | 0 | 0 | 0 |

TABLE 2-VI. FAILURE ANALYSIS RESULTS (Continued)

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| Motorola | | | | | | |
| (CA) MC5410L | 0 | 0 | 0 | 1 | 1 | 1 |
| (CB) MC9312L | 0 | 0 | 0 | 0 | 0 | 1 |
| (CE) MC5410BEX | 1 | 0 | 0 | 1 | 1 | 1 |
| (CF) MC9312BLX | 1 | 1 | 2 | 5 | 6 | 2 |
| (CJ) JM38510/00103 | | | | 0 | 2 | 2 |
| (CK) JM38510/01402 | | | | 0 | 4 | 3 |
| National | | | | | | |
| (DA) DM5410J | 0 | 0 | 2 | 1 | 1 | 2 |
| (DC) DM5472J | 2 | 3 | 3 | 4 | 4 | 2 |
| (DE) DM5410J/883B | 0 | 0 | 4 | 0 | 1 | 2 |
| (DG) DM5472/883B | 2 | 1 | 4 | 1 | 2 | 1 |

TABLE 2-VI. FAILURE ANALYSIS RESULTS (Continued)

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| (DJ) JM38510/00103 | | | | 1 | 0 | 1 |
| (DL) JM38510/00201 | | | | 1 | 3 | 3 |
| Signetics | | | | | | |
| (EA) S5410F | 0 | 0 | 4 | 1 | 0 | 1 |
| (EC) S5472F | 0 | 1 | 0 | 3 | 1 | 0 |
| (EE) RB5410F | 0 | 0 | 1 | 0 | 1 | 4 |
| (EG) RB5472F | 1 | 0 | 0 | 1 | 1 | 2 |
| (EJ) JM38510/00103 | | | | 1 | 2 | 2 |
| (EL) JM38510/00201 | | | | 0 | 2 | 1 |
| Texas Instruments | | | | | | |
| (FA) SN5410J | 1 | 0 | 1 | 1 | 0 | 1 |
| (FC) SN5472J | 1 | 2 | 3 | 10 | 0 | 2 |

TABLE 2-VI. FAILURE ANALYSIS RESULTS (Continued)

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| (FD) SN54S10J | 0 | 0 | 0 | 3 | 0 | 0 |
| (FE) SNC5410J | 7 | 1 | 0 | 0 | 0 | 0 |
| (FC) SNC5472J | VIC 36 | VIC 28 | VIC 29 | VIC 28 | 0 | 1 |
| (FH) SNC54S10J | 0 | 1 | 0 | 1 | 3 | 4 |
| (FJ) JM38510/00103 | | | | 0 | 1 | 1 |
| (FL) JM38510/00201 | | | | 1 | 1 | 0 |
| (FP) JM38510/00602 | | | | 1 | 4 | 3 |
| AMD | | | IOS | | | |
| (GB) 0713931251X | 8 | 1 | 10 | 3 | 1 | 0 |
| (GF) 0713931251X (883B) | 4 | 3 | 0 | 1 | 3 | 2 |
| (GK) JM38510/01402 | | | | 1 | 3 | 0 |
| Signetics | | | | | | |
| (EN) JM38510/00104 | | | | 0 | 1 | 2 |

**Quantities of failures shown include all failure modes. Only parameters which failed on ten or more devices were called out in the cells above.**

## FAILURE ANALYSIS

The data generated for the RADC guardband study was examined in a detailed analysis to determine major causes of device failures. The results of this work has been summarized in Table 2-VI. Major failure modes have been listed along with the number of failed parts for each device type at every temperature.

Table 2-VI has a total of 210 cells, each cell representing the test results of one group of devices, at one of three temperatures tested according to one of two test specifications. The distribution of failures is almost entirely contained in the 0 to 4 failure per group range. 75 groups have 0 failures, 61 groups have 1 failure, 31 groups have 2 failures, 18 groups have 3 failures, 13 groups have 4 failures, and 12 groups have 5 or more failures.

The Texas Instruments SN5472J (FC) devices had ten failures at 25° C to the military specification. Eight of these failures were due to IIL1, IIL2, and IIL3. The measured values were just under the lower limits. This would account for the tact that the devices passed the commercial specification because there is no lower limit placed on IIL.

The AMD 0713931251X (GB) devices had ten failures at -55°C to the commercial specification. All the failing devices had IOS values more positive than the limit of -35 milliamps. These same devices passed the MIL specification because IOS has a limit of -20 milliamps instead of -35 milliamps. In addition, seven of the devices also failed VOL with measured values of greater than 5 volts indicating that the output was actually in the high state rather than the low state. This occurs when the input thresholds do not meet the specified VILMAX and VIHMIN requirements.

The ITT 5410J/B2 (BE) devices had 16 failures at 25°C to the commercial specification. All but one of the failures was due to TPHL values greater than the specified limit of 15 nanoseconds. Most of the failing values were in the range of 15 to 18 nanoseconds, although one device had a value of 27 nanoseconds for one output pin. The same group of devices passed the military specification at 25°C because the upper limit for TPHL is 20 nanoseconds. At 125°C, 22 of these devices failed the military specification due to TPLH. The failing values were in the trange of 27 to 30 nanoseconds and the limit is 27 nanoseconds. The devices passed the commercial specification at 125°C because propagation delay measurements are not required.

The Texas Instruments SNC5472J (FG) devices had 36 failures at 25°C, and 29 failures at -55°C. In each case, the predominant failure was VIC. The failing values were in the range of -1.5 to -1.8 volts and the limit is -1.5 volts. The quantity of VIC failures is 28, 27, and 23 at 25°C, 125°C and -55°C respectively. The same devices that failed the commercial specification at 25°C also failed the military specification at 25°C. No failures occurred at 125°C and -55°C to the military specification because the VIC test is not performed.

In most cases where the quantity of failures to the MIL specification were found to be less than the quantity of failures to the commercial specification, it was the result of wider limits in the MIL specification. For cases where the difference in failure quantities are less than five, these differences may be due to random test problems such as poor contact, mechanical defects, or other problems not related to test specification or procurement grade.

TABLE 2-VII. FAILURE CLASSIFICATION BY FAILURE CATEGORY AND PROCUREMENT GRADE

| Procurement Grade | Commercial Test Spec. Failures | | | Military Test Spec. Failures | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| Commercial | 14<br>0.91 | 9<br>0.58 | 26<br>1.69 | 33<br>2.14 | 15<br>0.97 | 16<br>1.04 |
| 883B | 70<br>4.55 | 38<br>2.47 | 40<br>2.60 | 46<br>2.99 | 46<br>2.99 | 27<br>1.75 |
| JAN (MIL) | - | - | - | 8<br>1.04 | 19<br>2.47 | 19<br>2.47 |
| Total All Grades | 84<br>2.73 | 47<br>1.53 | 66<br>2.14 | 87<br>2.26 | 80<br>2.08 | 62<br>1.61 |

*NOTE: The top number is the quantity of device failures and the bottom number is the percent defective.

Table 2-VII shows the relationship between failure category and procurement grade. The failures are separated into six categories. The left half indicates the failures that occurred as a result of testing to the commercial specifications and the right half indicates the failures that occurred as a result of testing to the military specifications. Each of these groups is further divided into three columns for the three test temperatures. There are two numbers in each cell to indicate the failure quantity. The top number is the quantity of devices that failed and the bottom number is the percent defective. The percent defective was calculated on the basis of the total quantity of devices of each procurement grade that were tested. For the commercial and 883B procurement grades, each had 14 groups of nominally 110 devices which totals 1540 devices. The JAN devices had 14 groups of nominally 55 devices which totals 770 devices. The bottom row shows the total failure quantity and percent defective for each column.

The percent defective was calculated here on the basis of the total quantity of devices which were tested in that column. For the left half, this quantity is 3080 plus 770 or 3850 devices.

All the percent defective values lie in the range of about 1 to 3 percent with two exceptions. The commercial devices tested to the commercial specification at 125°C had a low value of 0.58 percent and the 883B devices tested to the commercial specification at 25°C had a high value of 4.55 percent. The latter was due to the TPHL failures of the BE devices and the VIC failures of the FG devices. In fact the percent defective of the first five cells of the 883B procurement grade would be reduced to less than half of their present values if the BE and FG devices had failure quantities typical of similar device types.

## CONCLUSIONS

The feasibility of electrical guardband testing is determined by a number of factors. The device, for which a guardband test procedure or specification is desired, must be a member of a mature family of devices so that process and design changes will not be a factor to contend with in limit determination. If a comprehensive specification is desired, the parameter distributions should not vary excessively as a function of manufacturer and datecode. The models chosen to perform the curve fitting and regression analysis should yield sufficiently high correlation factors to assure the predictability of parameter variation versus temperature. The selection of the model to be used may be done either by a trial and error method or by investigation of device physics to determine an exact relationship between temperature and the parameter under study. The definition of what is a sufficiently high correlation factor must be determined from the confidence level that the user wishes to maintain to insure that a device which passes or fails a guardband limit at 25°C would correspondingly pass or fail the normal limit at another temperature.

The results obtained in the analysis of parameter distributions as a function of manufacturer indicate that the parts display no significant variation. Due to the unavailability of a variety of datecodes for the majority of the devices, a detailed analysis of variation was limited. A cursory examination of cases where a variety did occur yielded the result that there was no significant variation due to datecode.

All of the devices chosen for this study are from mature technology families. The most recently developed technology involved was the Schottky clamp used on the 54S10 devices. Although all the devices were TTL, there is no reason why the same techniques could not be used for obtaining guradband test limits on devices from other mature families.

The three models chosen for the regression analysis were linear, log-linear, and exponential. Different values of correlation were obtained for each of these models. For the purpose of setting guardband limits, the model giving the highest correlation coefficient should be chosen. In a large majority of cases, the parametric correlation coefficients were in excess of 90 percent indicating that the models have a high degree of validity.

The performance of all three procurement grades appears to be similar. Most of the percent defective values are between about 1 and 3 percent. The percent defective of the commercial devices are slightly higher when tested to the military specification than when tested to the commercial specification at 25°C.

The 883B devices showed less compliance to the commercial specification than to the military specification. This was due to the large quantity of VIC failures (Ref. Failure Analysis Table) of the SNC5472J (FG) devices. Discussion with the manufacturer revealed a design anomaly as the cause of these failures. The problem has since been corrected. If these failures are ignored, the percent defective values in the first four columns of the 883B grade devices would drop to about half their present value. With the VIC failures removed, no significant differences can then be seen in the degree of compliance of 883B grade devices to the commercial and military specification. This tends to confirm the full electrical interchangeability between MIL-Spec. and commercial devices at least for these device types.

The total percent defective values also show no significant differences between the ability of the commercial and 883B test sample devices to comply with their procurement specifications and their ability to comply to the applicable military specification. This is probably because the MIL-Spec devices share a common design and processing base with their commercial counterparts.

On the basis of standard deviation, the JAN devices are in general better controlled than the 883B devices, and the 883B devices are better controlled than commercial. In other words, the degree to which parameter values are grouped together is greatest for JAN devices and least in commercial devices.

The mean values of the parameters for JAN, 883B, and commercial devices as tested by the MIL specification are very close together for nearly all parameters. This also indicates that there is a high probability that commercial and 883B parts are electrically interchangeable with MIL-Spec tested product although when commercial and 883B parts are tested to the MIL specification is lower yield may be obtained due to the wider spread of parameter values.

Once it has been determined what level of correlation coefficient is acceptable, guardband limits may be determined for all the parameters of all devices where feasible. These limits may then be incorporated into a revised test specification for use in facilities where environmental handlers are not available and to reduce the cost of testing to less than one third the cost of full temperature testing. Refer to Appendix 3 for a draft of a proposed MIL-STD-883 test method for guardband limit determination.

The results of the functional tests are given in Appendix 4. The data is presented in the same format as Table 2 - VI with the exception that no parameters have been listed. This is because the test results which were printed contain no diagnostic information but simply indicate pass or fail.

## FURTHER INVESTIGATION

The data generated for the RADC Guardband Study was examined in a detailed analysis to determine major causes of device failures. The results of this work are summarized in Table 2 - VI and Appendix 4.

The functional test failures are temperature related and usually occurred at 125°C with some failures noted at -55°C. Investigation into the failures indicate that the device input thresholds are temperature sensitive causing $V_{IH}$ to rise to the 2.0 volt limit at -55°C, while at 125°C, $V_{IL}$ drops below the 0.8 volt limit. These shifts represent a compromise in the device DC noise margin which could result in erratic device performance at the system level. Guardband limits could be set around the input threshold values: too low a value of $V_{IL}$ at 25°C will result in a functional device failure at 125°C; too high a value of $V_{IH}$ at 25°C will result in a functional device failure at -55°C.

In order to guarantee dynamic drive performance of a device, it is recommended that $T_{PHL}$, $T_{PLH}$, $T_{THL}$, and $T_{TLH}$, be performed with $R_L$=400 ohms and $C_L$=1000 pfd. Under this loaded output condition, the device rise and fall time can be accurately measured and used to determine the dynamic source and sink currents of the device. The faster the rise and fall time, the lower is the

output impedance of the device. A fast fall time (approximately 50 nanoseconds) would indicate that an excellent output drive circuit exists and could provide dynamic sink currents in excess of 50 milliamps. A fast fall time, therefore, would indicate a good bias exists on the lower transistor of the totem-pole output and probably would not fail the $V_{CL}$ test at -55°C. A fast rise time (approximately 150 nanoseconds) would indicate a low impedance path exists through the top transistor to $V_{CC}$ capable of providing dynamic source currents in excess of 20 milliamps.

It should be noted that these test suggestions appear to fill the gaps that exists in present guardband strategies. Can a device failure at the temperature extremes be predicted by using these tests? The real proof would be for these tests be performed on the same devices used in the guardband study.

It is the opinion of this contractor that the guardband testing approach is valid for mature, well controlled product. Use of properly developed guardbands in lieu of 100% testing at the temperature extremes provides obvious economic benefits that can positively reduce component costs without significantly reducing reliability.

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# APPENDIX 1
CODES

Appendix 1

TABLE A-I. CODES

| Code | Vendor | Part Number | Procurement Grade | Tested to |
|---|---|---|---|---|
| 1-1 | Fairchild | 5410 | COMM | COMM |
| 1-2 | Fairchild | 5410 | 883B | COMM |
| 2-1 | Fairchild | 54S10 | COMM | COMM |
| 2-2 | Fairchild | 54S10 | 883B | COMM |
| 3-8 | Fairchild | 9312 | 883B | COMM |
| 3-9 | Fairchild | 9312 | COMM | COMM |
| 4-1 | Fairchild | 5410 | COMM | JAN |
| 4-2 | Fairchild | 5410 | 883B | JAN |
| 4-3 | Fairchild | 5410 | JAN | JAN |
| 4-4 | ITT | 5410 | COMM | JAN |
| 4-5 | ITT | 5410 | 883B | JAN |
| 4-6 | ITT | 5410 | JAN | JAN |
| 4-7 | Motorola | 5410 | COMM | JAN |
| 4-8 | Motorola | 5410 | 883B | JAN |
| 4-9 | Motorola | 5410 | JAN | JAN |
| 4-10 | National | 5410 | COMM | JAN |
| 4-11 | National | 5410 | 883B | JAN |
| 4-12 | National | 5410 | JAN | JAN |
| 4-13 | Signetics | 5410 | COMM | JAN |
| 4-14 | Signetics | 5410 | 883B | JAN |
| 4-15 | Signetics | 5410 | JAN | JAN |
| 4-16 | Texas Instruments | 5410 | COMM | JAN |
| 4-17 | Texas Instruments | 5410 | 883B | JAN |
| 4-18 | Texas Instruments | 5410 | JAN | JAN |
| 5-1 | Fairchild | 5400 | JAN | JAN |
| 5-2 | Signetics | 5400 | JAN | JAN |
| 6-1 | ITT | 5410 | COMM | COMM |
| 6-2 | ITT | 5410 | 883B | COMM |
| 7-1 | Motorola | 5410 | COMM | COMM |
| 7-2 | Motorola | 5410 | 883B | COMM |
| 8-4 | Motorola | 9312 | 883B | COMM |
| 8-5 | Motorola | 9312 | COMM | COMM |
| 9-1 | Advanced Micro Development | 9312 | COMM | JAN |
| 9-2 | Advanced Micro Development | 9312 | JAN | JAN |
| 9-3 | Advanced Micro Development | 9312 | 883B | JAN |
| 9-4 | Motorola | 9312 | 883B | JAN |
| 9-5 | Motorola | 9312 | JAN | JAN |
| 9-6 | Motorola | 9312 | COMM | JAN |
| 9-8 | Fairchild | 9312 | 883B | JAN |
| 9-9 | Fairchild | 9312 | COMM | JAN |
| 10-1 | National | 5410 | COMM | COMM |
| 10-2 | National | 5410 | 883B | COMM |

TABLE A-I. CODES (Continued)

| Code | Vendor | Part Number | Procurement Grade | Tested to |
|---|---|---|---|---|
| 11-1 | National | 5472 | COMM | COMM |
| 11-2 | National | 5472 | 883B | COMM |
| 12-1 | National | 5472 | COMM | JAN |
| 12-2 | National | 5472 | 883B | JAN |
| 12-3 | National | 5472 | JAN | JAN |
| 12-4 | Signetics | 5472 | COMM | JAN |
| 12-5 | Signetics | 5472 | 883B | JAN |
| 12-6 | Signetics | 5472 | JAN | JAN |
| 12-7 | Texas Instruments | 5472 | COMM | JAN |
| 12-8 | Texas Instruments | 5472 | 883B | JAN |
| 12-9 | Texas Instruments | 5472 | JAN | JAN |
| 13-1 | Signetics | 5410 | COMM | COMM |
| 13-2 | Signetics | 5410 | 883B | COMM |
| 14-4 | Signetics | 5472 | COMM | COMM |
| 14-5 | Signetics | 5472 | 883B | COMM |
| 15-1 | Texas Instruments | 5410 | COMM | COMM |
| 15-2 | Texas Instruments | 5410 | 883B | COMM |
| 16-7 | Texas Instruments | 5472 | COMM | COMM |
| 16-8 | Texas Instruments | 5472 | 883B | COMM |
| 17-1 | Texas Instruments | 54S10 | COMM | COMM |
| 17-2 | Texas Instruments | 54S10 | 883B | COMM |
| 18-1 | Texas Instruments | 5483 | JAN | JAN |
| 19-1 | Advanced Micro Development | 9312 | COMM | COMM |
| 19-3 | Advanced Micro Development | 9312 | 883B | COMM |
| 22-1 | Fairchild | 54S10 | COMM | JAN |
| 22-2 | Fairchild | 54S10 | 883B | JAN |
| 22-3 | Texas Instruments | 54S10 | COMM | JAN |
| 22-4 | Texas Instruments | 54S10 | 883B | JAN |

TABLE A-II.

| Parameter Sequence Number* | Parameter Type |
|---|---|
| 1 | VOH |
| 2 | VOL |
| 3 | IIH |
| 4 | IIL |
| 5 | II |
| 6 | IOS |
| 7 | ICC |
| 8 | ICC |
| 9 | TPD |
| 10 | TPD |

*Valid for codes 4-1, 4-2, 4-3, 4-4, 4-5, 4-6, 4-7, 4-8, 4-9, 4-10, 4-11, 4-12, 4-13, 4-14, 4-15, 4-16, 4-17, 4-18, 5-1, 5-2, 22-1, 22-2, 22-3, 22-4, 1-1, 1-2, 6-1, 6-2, 7-1, 7-2, 13-1, 13-2, 3-8, 3-9

TABLE A-II. (Continued)

| Parameter Sequence Number* | Parameter Type |
|---|---|
| 1 | VOH |
| 2 | VOL |
| 3 | VIC |
| 4 | IIH |
| 5 | IIH |
| 6 | IIL |
| 7 | IIL |
| 8 | IOS |
| 9 | IOS |
| 10 | ICC |
| 11 - 29 | TPD |

*Valid for code 18-1

| Parameter Sequence Number* | Parameter Type |
|---|---|
| 1 | VOH |
| 2 | VOL |
| 3 | VIC |
| 4 | IIL |
| 5 | IIL |
| 6 | IIL |
| 7 | IIH |
| 8 | IIH |
| 9 | IIH |
| 10 | IIH |
| 11 | IIH |
| 12 | IOS |
| 13 | ICC |
| 14 | TPD |
| 15 | TPD |
| 16 | TPD |
| 17 | TPD |

*Valid for codes 11-1, 11-2, 12-1, 12-2, 12-3, 12-4, 12-5, 12-6, 12-7, 12-8, 12-9, 14-4, 14-5, 16-7, 16-8

| Parameter Sequence Number* | Parameter Type |
|---|---|
| 1 | VIC |
| 2 | VOL |
| 3 | VOH |
| 4 | IIH |
| 5 | IIL |
| 6 | II |
| 7 | IOS |
| 8 | ICC |
| 9 | ICC |

*Valid for codes 2-1, 2-2, 10-1, 10-2, 15-1, 15-2, 17-1, 17-2

TABLE A-II. (Continued)

| Parameter Sequence Number* | Parameter Type |
|---|---|
| 1 | VOH |
| 2 | VOL |
| 3 | IIL |
| 4 | IIH |
| 5 | II |
| 6 | IOS |
| 7 | ICC |
| 8 - 19 | TPD |

*Valid for codes 9-1, 9-2, 9-3, 9-4, 9-5, 9-6, 9-8, 9-9, 19-1, 19-3

| Parameter Sequence Number* | Parameter Type |
|---|---|
| 1 | VOH |
| 2 | VOL |
| 3 | VOL |
| 4 | IIL |
| 5 | IIL |
| 6 | IIH |
| 7 | ICC |

*Valid for codes 8-4, 8-5

TABLE A-III. PARAMETER DESCRIPTIONS

VOH - Output High Voltage Test
VOL - Output Low Voltage Test
VIC - Input Clamp Diode Test
IIL - Input Low Current
IIH - Input High Current
II - Input Leakage Current
IOS - Output Short Circuit Current
ICC - Supply Current
TPD - Propagation Delay

TABLE A-IV. DETERMINATION OF UNKNOWN QUANTITIES IN REGRESSION MODELS

The three model equations may be defined by:

$$(LIN) \quad Y = a_1 X + b_1$$

$$(LLIN) \quad Y = b_2 X^{a_2}$$

$$(EXP) \quad Y = e^{a_3 X + b_3}$$

| | Unknown | | | | | |
|---|---|---|---|---|---|---|
| Model | $a_1$ | $a_2$ | $a_3$ | $b_1$ | $b_2$ | $b_3$ |
| (LIN) | Slope | – | – | INT | – | – |
| (LLIN) | – | Slope | – | – | $e^{INT}$ | – |
| (EXP) | – | – | Slope | – | – | INT |

INT = Intercept

TABLE A-V. TEST NUMBERS (TN) AND PARAMETER TYPES

| Parameter Type | TN (5472 Devices) | TN (54S10, 5410 Devices) | TN (5483 Devices) | TN (9312 Devices) | TN (5400 Devices) |
|---|---|---|---|---|---|
| VOH | 1 | 201 | 1 | 201 | 201 |
| VOL | 5 | 301 | 6 | 301, 351 | 301 |
| VIC | 9 | 101 | 11 | 101 | 101 |
| IIL | 18 | 501 | 38 | 501, 551 | 501 |
| IIH | 28 | 401 | 20 | 401 | 401 |
| II | 40 | 601 | 38, 43 | 601 | 601 |
| IOS | 48 | 701 | 47 | 701 | 701 |
| ICC | 50 | 801, 901 | 52 | 801, 901 | 801 |
| TPD | 95 - 112 | 1101, 1201 | 85 - 120 | 1201 - 2308 | 1101 - 1208 |

# APPENDIX 2
# EXERPTS FROM COMPUTER REGRESSION AND HISTOGRAM ANALYSES

***REGRESSION ANALYSIS ( LIN)
DEVICE TYPE= 4
PROGRAM AT 22
TEMPERATURE=125

| PARAMETER SEQ. # | SLOPE | INTERCEPT | MEAN | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.5859E+00 | 0.1710E+01 | 0.7722E+00 | 0.4772E+00 |
| 2 | 0.5119E+00 | 0.1495E+00 | 0.5390E+00 | 0.6747E+00 |
| 3 | 0.3735E+00 | 0.3054E-04 | 0.4750E+00 | 0.1612E+00 |
| 4 | 0.6844E+00 | -.1342E-05 | 0.3069E+00 | 0.8327E+00 |
| 5 | 0.4474E+00 | 0.4251E-04 | 0.4864E+00 | 0.1201E+00 |
| 6 | 0.9549E+00 | 0.8982E-03 | 0.1242E-01 | 0.9935E+00 |
| 7 | 0.8577E+00 | 0.6834E-03 | 0.5963E-01 | 0.9694E+00 |
| 8 | 0.9508E+00 | 0.4775E-03 | 0.1535E-01 | 0.9925E+00 |
| 9 | 0.7167E+00 | 0.2095E-08 | 0.3796E+00 | 0.7879E+00 |
| 10 | 0.7732E+00 | 0.1101E-08 | 0.4167E+00 | 0.7649E+00 |

FISHER-INMIN STATISTIC FOR FUNCTIONAL TEST=0.2369E+00

***DEPENDENT VARIABLE IS PARAMETER AT 125 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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***REGRESSION ANALYSIS (LLIN)
DEVICE TYPE= 4
PROGRAM DE 22
TEMPERATURE=125

| PARAMETER SEQ. # | SLOPE | INTERCEPT | MEAN | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.4020E+00 | 0.0033E+00 | 0.7691E+00 | 0.4737E+00 |
| 2 | 0.5705E+00 | -.5159E+00 | 0.5351E+00 | 0.6827E+00 |
| 3 | 0.6441E+00 | -.1965E+01 | 0.9028E+00 | 0.5133E+00 |
| 4 | 0.9102E+00 | -.8104E+00 | 0.3066E+00 | 0.8356E+00 |
| 5 | 0.1454E+00 | -.7767E+01 | 0.8620E+00 | 0.5107E+00 |
| 6 | 0.1018E+01 | -.4939E-01 | 0.1259E-01 | 0.9937E+00 |
| 7 | 0.9161E+00 | -.4640E+00 | 0.6174E-01 | 0.9721E+00 |
| 8 | 0.9763E+00 | -.1400E+00 | 0.1543E-01 | 0.9926E+00 |
| 9 | 0.5586E+00 | -.8187E+01 | 0.3513E+00 | 0.8057E+00 |
| 10 | 0.8240E+00 | -.3566E+01 | 0.4156E+00 | 0.6664E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.2489E+00

***DEPENDENT VARIABLE IS PARAMETER AT 125 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

***REGRESSION ANALYSIS ( EXP)
DEVICE TYPE= 4
PROGRAM #= 22
TEMPERATURE=125

| PARAMETER SEQ. # | SLOPE | INTERCEPT | MEAN | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.1562E+00 | 0.7033E+00 | 0.7707E+00 | 0.4767E+00 |
| 2 | 0.1493E+01 | -.1636E+01 | 0.5495E+00 | 0.6798E+00 |
| 3 | 0.9528E+04 | -.1087E+02 | 0.9985E+00 | 0.4992E-01 |
| 4 | 0.6133E+03 | -.7449E+01 | 0.3069E+00 | 0.8413E+00 |
| 5 | 0.3253E+04 | -.9494E+01 | 0.7422E+00 | 0.5850E+00 |
| 6 | 0.1322E+02 | -.1654E+01 | 0.1204E-01 | 0.4944E+00 |
| 7 | 0.1023E+03 | -.5701E+01 | 0.6045E-01 | 0.9601E+00 |
| 8 | 0.4582E+02 | -.4874E+01 | 0.1524E-01 | 0.9955E+00 |
| 9 | 0.1164E+09 | -.1944E+02 | 0.3796E+00 | 0.7922E+00 |
| 10 | 0.1181E+09 | -.1967E+02 | 0.4167E+00 | 0.7688E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.2489E+00

***DEPENDENT VARIABLE IS PARAMETER AT 125 DEGREES,
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES,



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***REGRESSION ANALYSIS ( LIN)
DEVICE TYPE= 14
PROGRAM #= 4
TEMPERATURE=125

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.4729E+00 | 0.1804E+01 | 0.8184E+00 | 0.4268E+00 |
| 2 | 0.1046E+01 | 0.1148E-01 | 0.1807E+00 | 0.9055E+00 |
| 3 | 0.1416E+01 | 0.4027E-06 | 0.2024E-01 | 0.9894E+00 |
| 4 | 0.9138E+00 | -.1948E-04 | 0.3745E-01 | 0.9811E+00 |
| 5 | 0.5721E+00 | 0.6148E-05 | 0.7257E+00 | 0.5245E+00 |
| 6 | 0.9353E+00 | 0.9003E-04 | 0.6248E-01 | 0.9684E+00 |
| 7 | 0.9165E+00 | 0.9756E-04 | 0.5084E-01 | 0.9745E+00 |
| 8 | 0.9497E+00 | 0.5220E-04 | 0.1309E-01 | 0.9935E+00 |
| 9 | 0.1063E+01 | 0.1221E-08 | 0.2328E+00 | 0.8760E+00 |
| 10 | 0.9071E+00 | 0.2426E-09 | 0.6524E-01 | 0.9664E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.1153E-40

***DEPENDENT VARIABLE IS PARAMETER AT 125 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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***REGRESSION ANALYSIS (LLIN)
DEVICE TYPE= 14
PROGRAM #= 4
TEMPERATURE=125

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RMAN | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.4616E+00 | 0.6622E+00 | 0.8161E+00 | 0.4247E+00 |
| 2 | 0.9645E+00 | 0.3871E-01 | 0.1755E+00 | 0.9085E+00 |
| 3 | 0.9580E+00 | -.1103E+00 | 0.1660E-01 | 0.9907E+00 |
| 4 | 0.9820E+00 | -.1937E+00 | 0.3613E-01 | 0.9814E+00 |
| 5 | 0.1120E+01 | 0.1530E+01 | 0.7680E+00 | 0.4841E+00 |
| 6 | 0.1007E+01 | -.4554E-01 | 0.5846E-01 | 0.9704E+00 |
| 7 | 0.9629E+00 | -.2671E+00 | 0.4984E-01 | 0.9751E+00 |
| 8 | 0.9942E+00 | -.5015E-01 | 0.1295E-01 | 0.9933E+00 |
| 9 | 0.8934E+00 | -.1790E+01 | 0.2329E+00 | 0.8642E+00 |
| 10 | 0.9802E+00 | -.4373E+00 | 0.6256E-01 | 0.9685E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.1153E-40

***DEPENDENT VARIABLE IS PARAMETER AT 125 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.



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***REGRESSION ANALYSIS ( EXP)
DEVICE TYPE= 14
PROGRAM #= 4
TEMPERATURE=125

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.1424E+00 | 0.7433E+00 | 0.8197E+00 | 0.4250E+00 |
| 2 | 0.4017E+01 | -.2304E+01 | 0.1829E+00 | 0.9043E+00 |
| 3 | 0.1775E+06 | -.1277E+02 | 0.8864E-01 | 0.9547E+00 |
| 4 | 0.9411E+03 | -.7919E+01 | 0.3962E-01 | 0.9816E+00 |
| 5 | 0.7218E+05 | -.1213E+02 | 0.7695E+00 | 0.4626E+00 |
| 6 | 0.3031E+02 | -.4483E+01 | 0.6258E-01 | 0.9691E+00 |
| 7 | 0.2611E+03 | -.6698E+01 | 0.4906E-01 | 0.9767E+00 |
| 8 | 0.9550E+02 | -.5607E+01 | 0.1867E-01 | 0.9914E+00 |
| 9 | 0.7261E+08 | -.1896E+02 | 0.2281E+00 | 0.9015E+00 |
| 10 | 0.4035E+08 | -.1928E+02 | 0.6283E-01 | 0.9774E+00 |

FISHER-INNIN STATISTIC FOR FUNCTIONAL TEST=0.1153E-40

***DEPENDENT VARIABLE IS PARAMETER AT 125 DEGREES,
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES,

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***REGRESSION ANALYSIS ( LIN)
DEVICE TYPE= 3
PROGRAM NO 19
TEMPERATURE=-55

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | -.4454E-01 | 0.2924E+01 | 0.1001E+01 | -.7326E-01 |
| 2 | 0.5215E+00 | 0.1115E+00 | 0.6427E+00 | 0.6014E+00 |
| 4 | 0.1570E+01 | 0.4042E-03 | 0.5319E-01 | 0.9751E+00 |
| 4 | 0.2507E+00 | 0.6053E-06 | 0.8053E+00 | 0.4420E+00 |
| 5 | 0.4510E+00 | 0.6443E-06 | 0.6863E+00 | 0.5605E+00 |
| 6 | 0.7451E+00 | -.1517E-01 | 0.4696E+00 | 0.7311E+00 |
| 7 | 0.6479E-01 | 0.2547E-01 | 0.1007E+01 | 0.8588E-01 |

FISHER-(SMITH) TEST NOT PERFORMED
***DEPENDENT VARIABLE IS PARAMETER AT -55 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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***REGRESSION ANALYSIS (LLIN)
DEVICE TYPE= 3
PROGRAM #= 19
TEMPERATURE=-55

| PARAMETER SEQ. # | SLOPE | INTERCEPT | MBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | -.4662E-01 | 0.1071E+01 | 0.1001E+01 | -.7344E-01 |
| 2 | 0.6259E+00 | -.5670E+00 | 0.5926E+00 | 0.6419E+00 |
| 3 | 0.2706E+01 | 0.1157E+02 | 0.6110E-01 | 0.9691E+00 |
| 4 | -.6361E-01 | -.1552E+02 | 0.9869E+00 | -.1177E+00 |
| 5 | -.3953E-01 | -.1465E+02 | 0.9956E+00 | -.722ME-01 |
| 6 | 0.7962E+00 | -.5367E+00 | 0.4714E+00 | 0.7295E+00 |
| 7 | -.6563E-02 | -.3027E+01 | 0.1014E+01 | -.1195E-01 |

FISHER-IRWIN TEST NOT PERFORMED
DEPENDENT VARIABLE IS PARAMETER AT -55 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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***REGRESSION ANALYSIS ( EXP)
DEVICE TYPE= 3
PROGRAM #= 14
TEMPERATURE=-55

| PARAMETER SEQ. # | SLOPE | INTERCEPT | MBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | -.1223E-01 | 0.1056E+01 | 0.1001E+01 | -.7333E-01 |
| 2 | 0.1947E+01 | -.1905E+01 | 0.6248E+00 | 0.9185E+00 |
| 3 | 0.3165E+04 | -.1057E+02 | 0.1136E+00 | 0.9741E+00 |
| 4 | 0.9552E+05 | -.1457E+02 | 0.9975E+00 | 0.5734E-01 |
| 5 | 0.1260E+06 | -.1427E+02 | 0.9819E+00 | 0.1374E+00 |
| 6 | 0.1044E+02 | -.3585E+01 | 0.4711E+00 | 0.7367E+00 |
| 7 | 0.2342E+01 | -.3665E+01 | 0.1012E+01 | 0.4707E-01 |

FISHER-IRWIN TEST NOT PERFORMED
DEPENDENT VARIABLE IS PARAMETER AT -55 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.



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***REGRESSION ANALYSIS ( LIN)
DEVICE TYPE= 1
PROGRAM #= 17
TEMPERATURE=-55

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.9739E+00 | -.1068E+00 | 0.5365E+00 | 0.6812E+00 |
| 2 | 0.1267E+01 | -.1073E+01 | 0.2501E+00 | 0.8667E+00 |
| 3 | 0.3193E+00 | 0.3185E+00 | 0.9270E+00 | 0.2810E+00 |
| 4 | 0.2375E-02 | 0.5629E-07 | 0.1001E+01 | 0.6943E-02 |
| 5 | 0.8778E+00 | -.1165E-03 | 0.6166E-01 | 0.9687E+00 |
| 6 | 0.1296E+01 | 0.3333E-05 | 0.9732E-02 | 0.9968E+00 |
| 7 | 0.9229E+00 | 0.2717E-04 | 0.8672E-01 | 0.9558E+00 |
| 8 | 0.8914E+00 | 0.5099E-03 | 0.7229E-01 | 0.9635E+00 |
| 9 | 0.8760E+00 | 0.1437E-02 | 0.1654E+00 | 0.9036E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.6081E-74

***DEPENDENT VARIABLE IS PARAMETER AT -55 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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***REGRESSION ANALYSIS (LL IN)
DEVICE TYPE= 1
PROGRAM #= 17
TEMPERATURE=-55

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.8688E+00 | 0.7101E-01 | 0.5162E+00 | 0.6960E+00 |
| 2 | 0.1402E+01 | -.5372E+00 | 0.2516E+00 | 0.8649E+00 |
| 3 | 0.3156E+00 | -.5205E+00 | 0.9196E+00 | 0.2938E+00 |
| 4 | -.9584E-01 | -.1700E+02 | 0.9888E+00 | -.1111E+00 |
| 5 | 0.9002E+00 | -.6937E+00 | 0.6550E-01 | 0.9667E+00 |
| 7 | 0.9997E+00 | -.8226E-01 | 0.9371E-01 | 0.9521E+00 |
| 8 | 0.9149E+00 | -.4558E+00 | 0.7550E-01 | 0.9621E+00 |
| 9 | 0.9106E+00 | -.4032E+00 | 0.1622E+00 | 0.9163E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.6081E-74

***DEPENDENT VARIABLE IS PARAMETER AT -55 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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***REGRESSION ANALYSIS ( EXP)
DEVICE TYPE= 1
PROGRAM #= 17
TEMPERATURE=-55

| PARAMETER SEQ. # | SLOPE | INTERCEPT | RBAR | CORRELATION COEFFICIENT |
|---|---|---|---|---|
| 1 | 0.1138E+01 | -.1034E+01 | 0.5151E+00 | 0.6968E+00 |
| 2 | 0.4737E+00 | -.4092E+00 | 0.2516E+00 | 0.8650E+00 |
| 3 | 0.7078E+00 | -.1092E+01 | 0.9250E+00 | 0.2846E+00 |
| 4 | -.1046E+06 | -.1556E+02 | 0.9884E+00 | -.1126E+00 |
| 5 | 0.5901E+03 | -.7436E+01 | 0.5276E-01 | 0.9739E+00 |
| 7 | 0.1507E+02 | -.3802E+01 | 0.9503E-01 | 0.9515E+00 |
| 8 | 0.1109E+03 | -.5764E+01 | 0.6273E-01 | 0.9690E+00 |
| 9 | 0.4425E+02 | -.4855E+01 | 0.1543E+00 | 0.9208E+00 |

FISHER-IRWIN STATISTIC FOR FUNCTIONAL TEST=0.6081E-74

***DEPENDENT VARIABLE IS PARAMETER AT -55 DEGREES.
INDEPENDENT VARIABLE IS PARAMETER AT 25 DEGREES.

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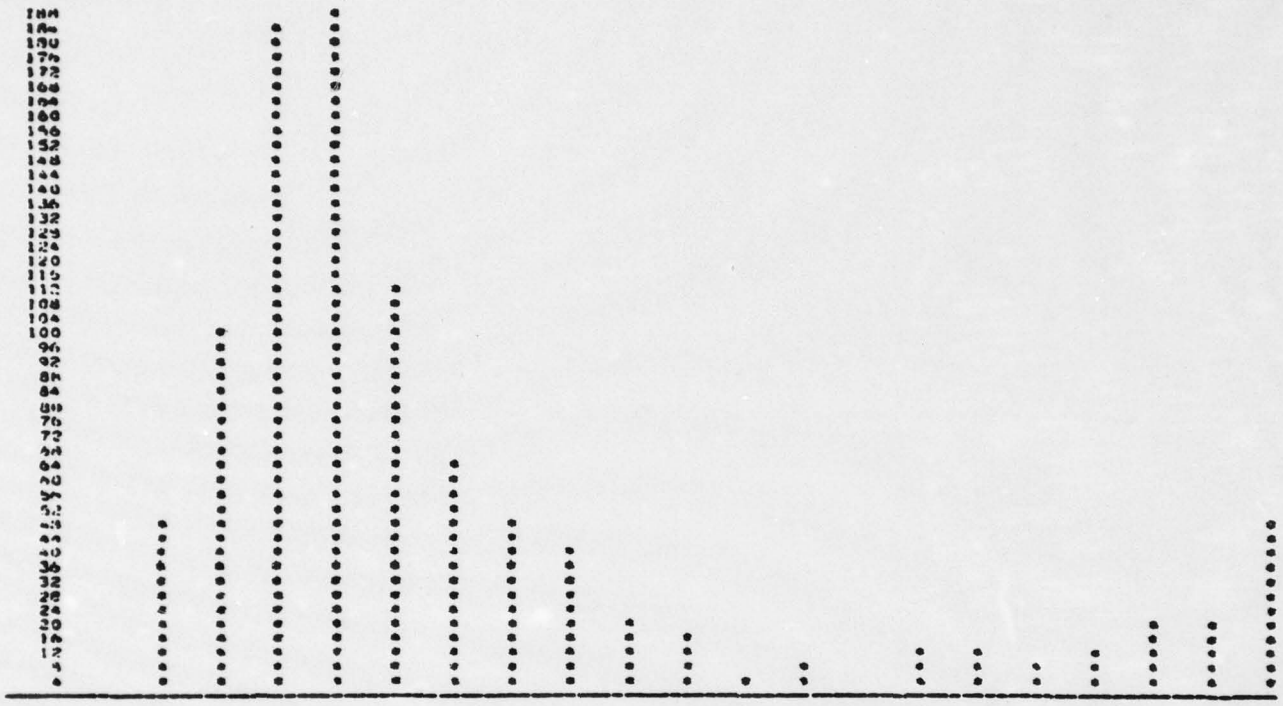
TNo= 401
DEV= 1
PCH # = 22
TEMP= 125

| MEAN | STD.DEV. | RANGE | MAX | S.SIZE | MED | 10% PT | SPEC LO | SPEC UP | UNDER | OVER |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.1566E-04 | 0.1065E-04 | 0.5310E-04 | 0.5300E-04 | 990 | 0.1170E-04 | 0.7200E-05 | 0.0 | 0.5000E-04 | 0 | 4 |

HISTOGRAM 125

| FREQUENCY | 48 | 103 | 185 | 190 | 113 | 65 | 49 | 42 | 22 | 18 | 6 | 9 | 3 | 12 | 12 | 9 | 14 | 20 | 20 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INTERVAL CLASS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

EACH • EQUALS 4 POINTS



CLASS INTERVAL TABLE

| CLASS INTERVAL | LOWER LIMIT | UPPER LIMIT |
|---|---|---|
| 1 | LESS THAN | 0.620000E-05 |
| 2 | 0.620000E-05 | 0.814444E-05 |
| 3 | 0.814444E-05 | 0.100889E-04 |
| 4 | 0.100889E-04 | 0.120333E-04 |
| 5 | 0.120333E-04 | 0.139778E-04 |
| 6 | 0.139778E-04 | 0.159222E-04 |
| 7 | 0.159222E-04 | 0.178667E-04 |
| 8 | 0.178667E-04 | 0.198111E-04 |
| 9 | 0.198111E-04 | 0.217556E-04 |
| 10 | 0.217556E-04 | 0.237000E-04 |
| 11 | 0.237000E-04 | 0.256444E-04 |
| 12 | 0.256444E-04 | 0.275889E-04 |
| 13 | 0.275889E-04 | 0.295333E-04 |
| 14 | 0.295333E-04 | 0.314778E-04 |
| 15 | 0.314778E-04 | 0.334222E-04 |
| 16 | 0.334222E-04 | 0.353666E-04 |
| 17 | 0.353666E-04 | 0.373111E-04 |
| 18 | 0.373111E-04 | 0.392555E-04 |
| 19 | 0.392555E-04 | 0.412000E-04 |
| 20 | GREATER THAN | 0.412000E-04 |

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# APPENDIX 3

## PROPOSED MIL-STD 833 TEST METHOD
## GUARDBAND LIMIT DETERMINATION

APPENDIX 3

PROPOSED MIL-STD-883 TEST METHOD

GUARDBAND LIMIT DETERMINATION

1. PURPOSE. The purpose of this method is to define a technique for determining guardband test limits for microelectronic devices. The resulting limits may then be incorporated in a guardband specification to provide a substitute for testing at temperature extremes. Because this method depends upon predictable behavior with respect to temperature, it is only applicable for devices which are fabricated according to well defined and mature processing technologies.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Guardband test. A guardband test is a test with modified parameter limits which is used as a substitute for testing at temperature extremes.

1.1.2 Correlation factor (C). The correlation factor is a number between minus one and plus one which describes the degree of linear dependence between two random variables. A value of one or minus one would indicate complete dependence and a value of zero would indicate complete independence.

1.1.3 Goodness of fit factor ($\bar{R}$). The goodness of fit factor is a number which describes the degree to which the relationship between two sets of values is approximated by a chosen mathematical function. A value of zero would indicate that the function exactly describes the relationship.

1.1.4 Guardband test temperature ($T_x$). The guardband test temperature is the temperature at which a guardband limit is to be used (typically 25°C).

1.1.5 Extreme test temperature ($T_y$). The extreme test temperature is a temperature at which testing is required in an existing procurement document. This is a temperature at which testing is desired to be eliminated.

1.1.6 Observed parameter value pair ($X_i$, $Y_i$). An observed parameter value pair is a pair of measured values for the $i_{th}$ observation of a particular parameter. $X_i$ is the value measured at temperature $T_x$ and $Y_i$ is the value measured at temperature $T_y$.

1.1.7 Sample size (n). The sample size is the total number of observations of a parameter value. If a parameter is measured only once per device, the sample size is the same as the quantity of devices. If a parameter is

measured more than once per device, the sample size is an integer multiple of the quantity of devices.

1.1.8 Linear model (LIN). The linear model is a mathematical function which has the form of a linear equation such that $g(X) = aX + b$.

1.1.9 Log-Linear model (LOG). The log-linear model is a mathematical function which has the form of a power equation such that $g(X) = bX^a$ or $\ell n g(X) = a\ell nX + \ell nb$.

1.1.10 Exponential model (EXP). The exponential model is a mathematical function which has the form of an exponential equation such that $g(X) = e^{aX + b}$ or $\ell n\, g\,(X) = aX + b$.

1.1.11 Specified test limits at temperature extreme ($Y_U$ $Y_L$). The specified test limits at temperature extreme are the limits which are imposed by an existing procurement document during the test at temperature $T_y$. $Y_U$ is the upper test limit and $Y_L$ is the lower test limit at temperature $T_y$.

1.1.12 Guardband test limits ($G_U$, $G_L$). The guardband test limits are the limits which are imposed during the test at temperature $T_x$ to provide an equivalent rejection criteria as the specified limits ($Y_U$, $Y_L$) at temperature $T_y$. $G_U$ is the upper guardband test limit and $G_L$ is the lower guardband test limit at temperature $T_x$.

2. APPARATUS. The apparatus will consist of suitable electrical equipment necessary to measure and record test parameter values as required by the applicable procurement documents, and other apparatus as required in the referenced test methods.

3. PROCEDURE

3.1 Obtain a group of at least 50 devices of the type for which guardband test limits are desired.

3.2 Serialize the devices.

3.3 Test the devices according to their procurement document and record the measured values, the serial number and the test temperature.

3.4 Select a parameter for which guardband limits are desired and calculate the values of the correlation between X and Y for the linear, log linear, and exponential models using the following equations.

$$C_{LIN} = \frac{n\sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{\sqrt{\left[n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2\right]\left[n\sum_{i=1}^{n} Y_i^2 - \left(\sum_{i=1}^{n} Y_i\right)^2\right]}}$$

$$C_{LOG} = \frac{n\sum_{i=1}^{n} \ln X_i \ln Y_i - \sum_{i=1}^{n} \ln X_i \sum_{i=1}^{n} \ln Y_i}{\sqrt{\left[n\sum_{i=1}^{n} \left(\ln X_i\right)^2 - \left(\sum_{i=1}^{n} \ln X_i\right)^2\right]\left[n\sum_{i=1}^{n} \left(\ln Y_i\right)^2 - \left(\sum_{i=1}^{n} \ln Y_i\right)^2\right]}}$$

$$C_{EXP} = \frac{n\sum_{i=1}^{n} X_i \ln Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} \ln Y_i}{\sqrt{\left[n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2\right]\left[n\sum_{i=1}^{n} \left(\ln Y_i\right)^2 - \left(\sum_{i=1}^{n} \ln Y_i\right)^2\right]}}$$

3.5 Compare the values of correlation and select the model which yields the highest absolute value. If the highest two absolute values of correlation agree to within ±0.01 then select both models for the following step in which the model equation coefficients are determined. If all three absolute values of correlation agree to within ±0.01 then select all three models for the following step.

3.6 Calculate the values of a and b according to the following formulas for the selected model.

a. Linear Model

$$a = \frac{n\sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2}$$

$$b = \frac{1}{n}\sum_{i=1}^{n} Y_i - \frac{a}{n}\sum_{i=1}^{n} X_i$$

b. Log-Linear Model

$$a = \frac{n\sum_{i=1}^{n} (\ell n\, Y_i\, \ell n\, X_i) - \sum_{i=1}^{n} \ell n\, Y_i \sum_{i=1}^{n} \ell n\, X_i}{n\sum_{i=1}^{n} (\ell n\, X_i)^2 - \left(\sum_{i=1}^{n} \ell n\, X_i\right)^2}$$

$$b = \exp\left\{\frac{1}{n}\sum_{i=1}^{n} \ell n\, Y_i - \frac{a}{n}\sum_{i=1}^{n} \ell n\, X_i\right\}$$

c. Exponential Model

$$a = \frac{n\sum_{i=1}^{n} X_i\, \ell n\, Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} \ell n\, Y_i}{n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2}$$

$$b = \frac{1}{n}\sum_{i=1}^{n} \ell n\, Y_i - \frac{a}{n}\sum_{i=1}^{n} X_i$$

3.7 If more than one model has been used for the determination of the model equation coefficients, calculate the value of the goodness of fit ($\overline{R}$) for each model using the appropriate equations below. Select the model which has the lowest value of $\overline{R}$ as the final model for guardband limit determination.

Linear Model: $$\overline{R} = \frac{\left(\frac{1}{n-2}\right)\sum_{i=1}^{n} (Y_i - aX_i - b)^2}{\left(\frac{1}{n-1}\right)\sum_{i=1}^{n} (Y_i - \overline{Y})^2}$$

Log-Linear Model: $$\overline{R} = \frac{\left(\frac{1}{n-2}\right)\sum_{i=1}^{n} (Y_i - bX_i^a)^2}{\left(\frac{1}{n-1}\right)\sum_{i=1}^{n} (Y_i - \overline{Y})^2}$$

Exponential Model: $$\overline{R} = \frac{\left(\frac{1}{n-2}\right)\sum_{i=1}^{n} (Y_i - e^{aX_i + b})^2}{\left(\frac{1}{n-1}\right)\sum_{i=1}^{n} (Y_i - \overline{Y})^2}$$

Where $$\overline{Y} = \frac{1}{n}\sum_{i=1}^{n} Y_i$$

3.8 Using the coefficients a and b, calculate the guardband limits by inserting the specified upper and lower limits at $T_y$ in the equations for the selected model.

Linear Model: $$G_U = \frac{Y_U - b}{a}, \quad G_L = \frac{Y_L - b}{a}$$

Log-Linear Model: $$G_U = e^{\frac{-\ell nb}{a}} Y_U^{\frac{1}{a}}, \quad G_L = e^{\frac{-\ell nb}{a}} Y_L$$

Exponential: $$G_U = \frac{\ell n\, Y_U - b}{a}, \quad G_L = \frac{\ell n\, Y_L - b}{a}$$

3.9 Compare the calculated limit to the specified limit at $T_x$. If the calculated limit is more restrictive than the specified limit at $T_x$, use the calculated limit as the guardband test limit. If the specified limit at $T_x$ is more restrictive than the calculated limit, retain the specified limit at $T_x$ as the guardband test limit.

3.10 Repeat steps 3.4 through 3.9 for each parameter for which guardband limits are desired.

4. SUMMARY. The following details must be specified in the applicable procurement document:

a. The maximum and minimum guardband limits as determined by the procedure in this test method.

b. The minimum sample size required for limit determination.

c. The minimum correlation factor (in absolute value).

d. The maximum goodness of fit factor.

# APPENDIX 4

# SPECIAL ELECTRICAL STRESS TESTS

## SPECIAL ELECTRICAL STRESS TESTS

After completion of all electrical testing required for the data analysis phase of the guardband study, all the JAN, 883B, and commercial grade 5410 and 5472 devices were subjected to special electrical stress tests. These tests were done in accordance with the test tables of Attachment I and Attachment II of the Statement of Work.

Five different parameters were measured for the stress tests. The parameter names are IMAX, BVIN, ICCLK, IILK, and IOLK. The IMAX tests is a measure of ICC with VCC at 8.0 volts and the device inputs at either ground or 5.0 volts. The BVIN test determines the input breakdown voltage with 1 milliamp input current and VCC at 5.5 volts. The ICCLK test requires all inputs to be grounded while measuring the value of ICC with VCC at 0.4 volt. IILK is the input leakage current with 4.5 volts applied to the input under test and all other inputs and VCC at ground. IOLK is the output leakage current with 5.5 volts applied to the output under test and all inputs and VCC connected to ground.

In each case, a sample of 10 devices was first subjected to the test. Failure of 6 or more of this sample would have terminated the testing of that group. In no case did 6 or more devices fail the sample test and the remainder of devices in each group was tested. After testing all the devices of a group, the percent failure was determined. Failure of 25 percent of more of the group would have required that a representative sample depicting a like failure mode be failure analyzed. Table I summarizes the failures for all the groups tested by part type, manufacturer, and procurement grade. It can be seen that at no time did the failure rate equal or exceed 25 percent. Table II is a summary of the failures encountered, grouped by part type, parameter, and procurement grade. The number of failures listed here is the number of times that a parameter failed which may differ from the number of devices that failed because some parameters are measured more than once per device and some devices failed more than one parameter. The most prominent failures that occurred were IMAX for all procurement grades of the 5410, IMAX and ICCLK for the commercial 5472, and ICCLK for the 883B 5472. The largest failure quantity overall was ICCLK for the 5472.

A hard copy printout of all tests and measurements performed was prepared for all microcircuits tested. The printout contains the following information:

1. Test head identification (STATIA)
2. Test plan name (G5472 or G5410)
3. Test execution sequence number (SN)
4. Device serial number *
5. Date of test
6. Temperature of device ambient
7. Test parameter name
8. Device pin number
9. Measured value
10. Upper and lower parameter limits followed by the word 'FAIL' for all failures.

* The serial number prefix carries part type, manufacturer, and procurement grade information. See Table 1-1 of the final report for serial number prefix cross reference.

TABLE I. SPECIAL ELECTRICAL TEST FAILURE SUMMARY

| PART TYPE | VENDOR | FAILURES | | | | | |
|---|---|---|---|---|---|---|---|
| | | COMM | | 883B | | JAN | |
| | | QTY | % | QTY | % | QTY | % |
| 5410 | FAIRCHILD | 1 | 0.9 | 7 | 6.4 | 0 | 0 |
| " | ITT | 5 | 4.6 | 8 | 7.3 | 1 | 1.8 |
| " | MOTOROLA | 1 | 0.9 | 1 | 1.3 | 1 | 1.8 |
| " | NATIONAL | 7 | 6.4 | 3 | 2.7 | 1 | 1.8 |
| " | SIGNETICS | 3 | 2.7 | 3 | 2.7 | 1 | 1.8 |
| " | TEXAS INST. | 1 | 0.9 | 1 | 0.9 | 1 | 1.8 |
| 5472 | NATIONAL | 13 | 11.8 | 13 | 11.8 | 5 | 9.1 |
| " | SIGNETICS | 20 | 18.2 | 12 | 10.9 | 3 | 5.5 |
| " | TEXAS INST. | 5 | 4.6 | 4 | 3.6 | 0 | 0 |

TABLE II. SPECIAL ELECTRICAL TEST FAILURE SUMMARY BY PARAMETER

| PART TYPE | PARAMETER | FAILURE QUANTITY | | | |
|---|---|---|---|---|---|
| | | COMM | 883B | JAN | TOTAL |
| 5410 | IMAX | 7 | 6 | 5 | 18 |
| " | BVIN | 1 | 10 | 2 | 13 |
| " | ICCLK | 4 | 2 | 1 | 7 |
| " | IILK | 9 | 3 | 1 | 13 |
| " | IOLK | 5 | 11 | 2 | 18 |
| 5472 | IMAX | 24 | 10 | 0 | 34 |
| " | BVIN | 5 | 4 | 3 | 12 |
| " | ICCLK | 34 | 22 | 2 | 58 |
| " | IILK | 12 | 6 | 3 | 21 |
| " | IOLK | 15 | 16 | 1 | 32 |

TABLE III. FAILURE ANALYSIS RESULTS

FUNCTIONAL TESTS

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| Motorola | | | | | | |
| (CA) MC5410L | 0 | 0 | 0 | 72 | 94 | 109 |
| (CB) MC9312L | 25 | 4 | 4 | 6 | 5 | 10 |
| (CE) MC5410BEX | 1 | 5 | 4 | 1 | 1 | 5 |
| (CF) MC9312BLX | 11 | 15 | 6 | 5 | 5 | 31 |
| (CJ) JM38510/00103 | | | | 0 | 47 | 53 |
| (CK) JM38510/01402 | | | | 0 | 3 | 11 |
| National | | | | | | |
| (DA) DM5410J | 0 | 19 | 39 | 0 | 1 | 25 |
| (DC) DM5472J | 2 | 14 | 3 | 2 | 0 | 0 |
| (DE) DM5410J/883B | 0 | 0 | 0 | 0 | 2 | 0 |
| (DG) DM5472/883B | 3 | 28 | 4 | 4 | 0 | 0 |

TABLE III. FAILURE ANALYSIS RESULTS (Continued)

FUNCTIONAL TESTS

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| (DJ) JM38510/00103 | | | | 1 | 9 | 55 |
| (DL) JM38510/00201 | | | | 0 | 0 | 0 |
| Signetics | | | | | | |
| (EA) S5410F | 0 | 6 | 10 | 0 | 104 | 37 |
| (EC) S5472F | 0 | 0 | 0 | 3 | 0 | 0 |
| (EE) RB5410F | 0 | 0 | 1 | 0 | 89 | 91 |
| (EG) RB5472F | 0 | 0 | 0 | 5 | 0 | 0 |
| (EJ) JM38510/00103 | | | | 1 | 43 | 55 |
| (EL) JM38510/00201 | | | | 0 | 0 | 0 |
| Texas Instruments | | | | | | |
| (FA) SN5410J | 1 | 0 | 110 | 0 | 0 | 7 |
| (FC) SN5472J | 1 | 109 | 1 | 1 | 0 | 0 |

TABLE III. FAILURE ANALYSIS RESULTS (Continued)

FUNCTIONAL TESTS

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| (FD) SN54S10J | 12 | 1 | 85 | 3 | 0 | 25 |
| (FE) SNC5410J | 4 | 3 | 103 | 0 | 1 | 13 |
| (FG) SNC5472J | 8 | 32 | 7 | 0 | 0 | 0 |
| (FH) SNC54S10J | 0 | 0 | 11 | 0 | 2 | 4 |
| (FJ) JM38510/00103 | | | | 0 | 1 | 53 |
| (FL) JM38510/00201 | | | | 0 | 0 | 0 |
| (FP) JM38510/00602 | | | | 1 | 0 | 0 |
| AMD | | | | | | |
| (GB) 0713931251X | 4 | 99 | 15 | 2 | 1 | 0 |
| (GF) 0713931251X (883B) | 33 | 74 | 12 | 110 | 110 | 31 |
| (GK) JM38510/01402 | | | | 1 | 2 | 13 |
| Signetics | | | | | | |
| (EN) JM38510/00104 | | | | 32 | 40 | 0 |

TABLE III. FAILURE ANALYSIS RESULTS (Continued)

FUNCTIONAL TESTS

| Manufacturer Part Number | Comm. Mfr. Spec. | | | Jan. Spec. | | |
|---|---|---|---|---|---|---|
| | 25°C | 125°C | -55°C | 25°C | 125°C | -55°C |
| Fairchild | | | | | | |
| (AA) 9N10DM | 0 | 0 | 1 | 2 | 1 | 103 |
| (AD) 9S10DM | 2 | 6 | 36 | 2 | 4 | 3 |
| (AE) 9N10DMQB | 0 | 1 | 0 | 1 | 92 | 100 |
| (AH) 9S10DMQB | 4 | 1 | 104 | 1 | 1 | 26 |
| (AF) 9312DMQB | 24 | 29 | 9 | 1 | 3 | 2 |
| (AJ) JM38510/00103 | | | | 1 | 37 | 46 |
| (AN) JM38510/00104 | | | | 30 | 48 | 1 |
| ITT | | | | | | |
| (BA) ITT5410J | 0 | 4 | 0 | 0 | 6 | 1 |
| (BJ) JM38510/00103 | | | | 0 | 42 | 50 |
| (BE) ITT5410J/B2 | 3 | 47 | 14 | 4 | 99 | 29 |

## GLOSSARY OF TERMS

**$V_{OL}$... Low-level Output Voltage**

The voltage at an output terminal for a specified output current with input conditions applied which according to the product specification will establish a low level at the output.

**$V_{OH}$... High-level Output Voltage**

The voltage at an output terminal for a specified output current with input conditions applied which according to the product specification will establish a high level at the output.

**$I_{IH}$... High-level Input Current**

The current flowing out of an input when a specified voltage is applied to that input.

**$I_{IL}$... Low-level Input Current**

The current flowing into an input when a specified voltage is applied to that input

**$I_{OS}$... Short-circuit Output Current**

The current that flows into an output when that output is short-circuited to ground with input conditions applied to establish the output logic level farthest from ground potential.

**$I_{CC}$... Supply Current**

The current flowing into the indicated supply terminal.

**$f_{MAX}$... Maximum Clock Frequency**

The highest rate at which the clock input can be driven while maintaining intellegent transitions at the output.

$t_r$...Rise Time

The time between a specified low-level voltage and a specified high-level voltage on a waveform which is changing from the defined low-level to the defined high-level.

$t_f$...Fall Time

The time between a specified high-level voltage and a specified low-level voltage on a waveform which is changing from the defined high-level to the defined low-level.

$t_{PLH}$...Propagation Delay Time, Low-to-high-level

The time between the specified reference points on the input and output voltage waveforms with the output changing from the defined low-level to the defined high-level.

$t_{PHL}$... Propagation Delay Time, High-to-low-level

The time between the specified reference points on the input and output voltage waveform with the output changing from the defined low-level to the defined high-level.

$t_{TLH}$...Transition Time, Low to High Level

The time between a specified low level voltage and a specified high level voltage on a waveform that is changing from the defined low level to the defined high level.

$t_{THL}$...Transition Time, High to Low Level

The time between a specified high level voltage and a specified low level voltage on a waveform that is changing from the defined high level to the defined low level.

$V_{CE(SAT)}$...Saturation Voltage Collector-to-emitter

The dc voltage between collector and emitter terminals for specified saturation conditions.

VIC...Input Clamp Voltage

An input voltage in a region of relatively low differential resistance that serves to limit the input voltage swing.

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